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# QUARTERLY PAPERS

ON

# ENGINEERING.

## VOLUME IV.

THIRTY-EIGHT ENGRAVINGS.

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TO

SIR JOHN RENNIE, C.E., F.R.S.,

ETC., ETC., ETC.,

PRESIDENT OF THE INSTITUTION OF CIVIL ENGINEERS,

THIS VOLUME,

BEING THE FOURTH DEVOTED TO SUBJECTS CONNECTED WITH THE PROFESSION
OF WHICH HE IS SO DISTINGUISHED A MEMBER,

IS INSCRIBED, WITH MUCH RESPECT,

BY HIS VERY HUMBLE SERVANT,

JOHN WEALE.

August 12th, 1845.

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## PART VII.



## PART VIII.

ON THE

# APPLICATION OF ATMOSPHERIC PRESSURE

TO

# RAILWAYS.

By Mr. T. HARRIS, Student in Civil Engineering.

In the present arrangement for propelling carriages by atmospheric pressure, an exhausting apparatus is applied to the extremity of tubes of about three miles in length, the trains running along the rails between each successive stage by their own momentum. This arrangement supposes the employment of as many exhausting engines as there are stages or intervals of pipe in the length of the road, as at A, B, C, &c., Fig. 1; an arrangement which is not without some considerable objection, inasmuch as each engine will only be at work during the progress of the train over one stage of pipe, which will only be for a few minutes.

It may, therefore, be worthy of consideration, in what manner the number of engines may be diminished, and the moving force applied at any instant of time to any one or more stages of pipe, so as to have only as many engines at work as will be adequate to supply the constant demand of force, and no more.

It is very clear that the engine at (A) when it has pumped the train over the stage 1, could, if transferred to B, pump it over the portion 2, and if transferred to C, over the portion 3, and so on; and that in fact one engine would be quite sufficient to work one train along the whole line, if it could be brought into connexion at any instant with any stage of pipe.

Now by having, as in Fig. 2, a second pipe A, B, running the whole length of the line, laid in any manner most convenient, each stage of pipe 1, 2, 3, 4, &c., being

connected at both ends, by means of stop cocks or valves, with this second pipe as at C, D, &c., an exhausting engine at A may be brought into communication with either of the stages 1, 2, 3, &c., by opening one of these valves, and thus the train might be propelled along the whole line by a single engine. The second pipe, being a vacuum, would further act as a large reservoir of force, which could be brought into connexion with any one or more stages of the propelling tubes, and thus instantly set the train in motion at any required moment, and as instantly stop it again; the engine continuing to work on the lower tube, A, B, without intermission.

By having a double piston as at A, B, Fig. 3, and valves at each extremity of every stage of the propelling tubes, as at C and D, the train may be made to traverse either backward, or forward, without reversing the piston, which would be a great convenience; as also in backing a train, in case it should overshoot an intermediate station E, Fig. 3, where it was required to stop; for by closing the valve D, opening C, and connecting the end D with the secondary tube, the carriage would run from C to D; also by closing the valve at C, opening D, and putting the extremity C into communication with the secondary pipe, the train would run from D to C, the piston plug B acting in the one case, and the piston plug A in the other. Of course the train could not move from C to D unless the valve at C were opened to allow the air to rush in behind the piston A, as the back piston A would tend, by its advancing, to create a vacuum, and thus balance the vacuum between the piston B and extremity D; and vice versâ when the train is going from D to C. Fig. 4 is illustrative of this process.

It only remains to consider, the number of engines which would be required to work a certain number of trains at the same time on a line of railway; now, as one engine could work one train, of course two engines could work two trains, three engines three trains on the line, all at the same time, and so on; therefore, it appears there would be as many engines required as the greatest number of trains which would be likely to be at work on the line at the same time; thus if there were six trains at work at the same time, (viz.) three up and three down trains, six engines would bè required and no more, all these engines being connected with the second pipe, and continually at work on it; and thus on a line of sixty miles in length, six engines would do the work of twenty; supposing six trains the greatest number likely to be on the lin[illegible]ce.

There would also be an advantage gained, in consequence of the engines being continually working during the stoppages of the trains on the line, so that the engines would never be idle; and if the diameter of the vacuum pipe was only equal to that of the propelling pipes, we should, upon opening a communication with either stage, have an almost instantaneous exhaustion, in consequence of the capacity of the

vacuum pipe being so very much greater than that of a single stage of the propelling pipes, since the former runs the whole length of the line.

Fig. 4 represents a working model which I have lately constructed on this principle, and which works freely either way by opening a communication at either end with the secondary pipe.

In this model A, B is the secondary pipe, and C and D the valvular communications at the extremities of the motive pipe, when either extremity as C, is put into communication with the secondary pipe, the tube M is closed and the tube N opened, and reciprocally so as to admit the air freely behind the piston.

The requisite signals for opening or closing the communications with the motive pipe would be readily made by means of the electrical telegraph.

# INTRODUCTION.

In the latter part of the year 1842, I was called upon by Mr. James Pim, Jun., of Dublin, to devote my thoughts to the possibility of improving the means of obtaining the vacuum for use upon atmospheric railways. The experimental Dalkey line had just then, I believe, been determined on; and Mr. Pim stated that it was an object of the highest importance to those interested in the Atmospheric Railway Patent, to devise means for obtaining the vacuum, more efficient and economical than had up to that time been proposed; namely, than exhaustion by the air-pump, of the main direct. The following three Reports were the results of the consideration which I accordingly gave to the subject, and which were communicated in November and December, 1842, to Mr. James Pim, Jun., and at his request to Mr. Bergin, Dr. Robinson, Ast. Royal, Armagh, and to the late Mr. Jacob Samuda. I also consulted my excellent and learned friend, Dr. Apjohn, T.C.D., upon the conclusions I had arrived at. The proposals of improvement contained in these Reports, or my discoveries and inventions, (if I may so characterize them,) were ably investigated in a rigid form by Dr. Robinson, whose calculations were submitted to me subsequently, and less fully, by Dr. Apjohn; and by these parties, together with Mr. Pim and Mr. Bergin, were they admitted as having been fully established, and their results to be of the utmost possible importance as regarded the future economic working of atmospheric railways. Mr. Jacob Samuda, alone, was or affected to be of a totally different opinion; the only semblance of an argument against my views, however, which I was at any time able to obtain from him, either orally or written, was a memorandum or calculation as to the properties of my vacuum reservoirs, of which a verbatim copy is given in the Appendix. (No. 9.) The style of this document, and the methods of calculation which it reveals, will probably enable those who are versed in pneumatic investigations to decide how far this gentleman was competent to the examination of such questions.

The first Report contains the developement of my plan for using the *air-pump*,

*worked by a comparatively small power, for the constant exhaustion of air-tight reservoirs or vacuum vessels, to be brought into communication with the atmospheric main when it became necessary to share their vacuum therewith.* The results given as to power and effect are calculated upon the experimental data, horse power unit, &c., given by Professor Barlow in his able Report to the President of the Board of Trade, presented to Parliament in 1842. The main conclusions, and all the important parts of Professor Barlow's Report, remain to the present hour unshaken; but Mr. Bergin, being at the above period engaged in the publication of his "Observations" upon this Report, in which he assumed some different data, as to leakage, unit of horse power, &c., I was requested by Mr. Pim to recalculate my results, adopting Mr. Bergin's data. These are embodied in the second Report, together with a description of some details of arrangement, proposed by me for the practical working of an atmospheric line upon my method of exhaustion, and ridding it of a practical difficulty or objection suggested by Dr. Robinson. The third Report enunciates my invention of *the method of obtaining vacuum for atmospheric railways by the direct condensation of steam in close vessels or reservoirs, capable of being brought into communication with the main,* and investigates its conditions as to power and effect; it also contains comparative estimates of the outlay for exhausting apparatus, as do also the two former Reports. The first Report likewise contains some observations upon the use of water-wheels, combined with steam-power, as a supposed means of economizing power, for obtaining vacuum, and upon obtaining it by means of the direct emptying of water from close vessels, by pipes, having a fall of more than 34 feet. This may be called the "Torricellian method," a slightly modified arrangement of which has been recently patented by Messrs. Samuda*.

As these Reports were desired to carry conviction to unmathematical readers, I was compelled to forego any attempt at generality, and adhere to mere arithmetical demonstration in treating my subject. I trust this will explain the inelegance of method which they present.

These Reports, together with the drawings which accompanied them, are now published for two principal reasons. First, that I believe the matter which they contain must continue hereafter to form a not unimportant element in all future inquiries or calculations as to the economic working of atmospheric railways, and as removing altogether the most formidable valid objection ever made against this system, quo ad cost, as compared with the locomotive, namely, that "the relative expenses of working depend entirely upon the daily amount of traffic;" or, in Professor Barlow's

* See Repertory of Arts, February, 1845.

words, (Report, page 5,)—"The fact is, that in one case (*the atmospheric*) the expenses per diem will be nearly the same, whether working at intervals of an hour, or at every quarter of an hour, whereas in the other (*the locomotive*) the charge is nearly proportionate to the work actually performed." The object of my methods of exhaustion, and that which with other advantages they fully achieve, is in this respect to raise the atmospheric system to a level with the locomotive, in making the expenditure of power for any variable traffic strictly proportionate to the work done. In stating this, I wish not to be misunderstood as pronouncing any opinion whatever upon the general relative merits of the two systems. This rests upon many other important questions besides that of expenditure for power. What I do affirm is this, that the expenditure for power, on the atmospheric system, is capable of being reduced, by the means I have pointed out, very much below what was considered inevitable by its projectors themselves, in the year 1842, or than was possible by any system of exhaustion by them or others then devised, or as yet constructed, or up to a recent period proposed being constructed by any one but myself. My second reason for publication is to assert my right in priority of invention against several parties, who have either re-invented or claimed as their own various portions of the discoveries contained in these Reports.

In the Appendix this question will be found fully treated, and the necessary documents given to sustain proof of the date of publication of my inventions, together with such other information as will enable those interested in the progress of atmospheric railways to judge hereafter to whom the improvements here alluded to are due.

ROBERT MALLET,
MEM. INST. C.E.

London, 10th June, 1845.

# THREE REPORTS

UPON

## IMPROVED METHODS OF CONSTRUCTING AND WORKING

# ATMOSPHERIC RAILWAYS.

BY ROBERT MALLET, ESQ., A.B.,

MEM. INST. C.E., M.R.I.A., HON. MEM. R.S.S.A., ETC., ETC.

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## REPORT I.

### OF THE MEANS OF STORING THE VACUUM, AND ITS EFFECTS.

18th November, 1842.

In the present plan of producing the vacuum just as it is wanted, by providing adequate power to do so, the expense of power per day will be about the same, whether the number of trains be few or many. In the locomotive system, on the contrary, the charges for power are nearly in proportion to the distance traversed with the same load, or generally in proportion to the work done.

My object then is to provide means of husbanding the vacuum, or obtaining a magazine of vacuum power, so that *a smaller engine and air-pump* may be used and kept *constantly at work.*

This I purpose to effect by causing the air-pump to exhaust one or several large hollow vessels of boiler plate, made air-tight, and capable of having communication made with the line of railway pipe, by valves.

The capacity of these vessels to be greater than that of the railway pipe, and a vacuum being constantly maintained in these, on opening communication between them and the railway pipe, the tendency to equilibrium will produce a certain amount of vacuum in the latter.

From the greater capacity of these vacuum vessels than that of the railway tube, and from the continuous action of the engine, this vacuum in the tube will be nearly or sufficiently constant during the passage of a train.

The moment a train has passed, the valve of communication between the vacuum vessel and the tube is closed; and as these vessels may be made absolutely air-tight, the power wasted in the present plan of exhaustion from *a constantly leaking vessel* will be avoided, except during the short period of the transit of the train; while

during the intervals between the trains the engine will be constantly at work, exhausting absolutely air-tight vessels, and providing the vacuum husbanded in these vessels ready for use when required.

So that in place of the measure of power of the engine to be employed being that required to meet the loss by leakage and total discharge of the railway tube *during* the passage of the train, it becomes this amount diminished in the ratio of the time between the trains to the time of their passage; thus if on a given line of railway the engine would, on the present plan, be one half its time idle, I propose to use an engine of about one half the present power and maintain it always at work, and so of every other proportion.

Thus the original outlay, as well as the cost of working, will be in proportion to the work done, or number of trains passed in a given time, and the atmospheric system can again compare in this respect with the locomotive.

On the present system "there must be sufficient leakage discharging power provided for the whole length of tube, although that power becomes in excess after the carriages have advanced a short way,"[a] but the "actual lost power by leakage is only that due to half the length of tube during the transit of the trains."[b] Yet this cannot be taken any advantage of by the present mode of exhaustion; it is, however, fully taken advantage of by my method.

The objects which I propose to attain are:—1st. The employment of much smaller engine-power than that indicated by Professor Barlow's experiments and report, or as yet proposed by any one else.

2nd. The proportioning such reduced engine-power to the work to be done, *i. e.* to the actual number of trains to be passed in the day. (NOTE.—In putting down such engines provision may be made to meet future increased traffic by working expansively at first, and altering this afterwards up to full steam.)

3rd. The keeping such *reduced engine power constantly at work* in producing a magazine of power to be drawn upon as wanted.

From these there follow as consequential advantages: 1st. That no power is lost or wasted by exhausting out of a leaking vessel or tube *preparatory* to the passage of a train, but only *during* the passage of the train.

2nd. That the tube can be almost *instantly* exhausted, ready to pass the train upon the signal being made to do so, by merely opening a valve. By this quick exhaustion greater staunchness of the long valve will be insured.

3rd. That the moment the train has passed, and the valve communicating between the vacuum vessel and tube is shut, the whole power of the engine applied to the air-pump becomes again effective in accumulating power.

[a] Barlow, Report, p. 12. [b] Ibid.

4th. That the height of the vacuum gauge will remain much more steady during the entire transit of a train than is possible at present even by a disproportionate waste of power.

5th. That much greater lengths of tube may be advantageously worked, and with diminished power, than can be on the existing plan.

6th. That the motion of a train may be preserved quam proxime uniform during its entire time of transit, which is impossible on the existing method of exhaustion.

7th. That the economy of my mode increases (employing the same proportionate power) with the area of the tube, because by the present plan the larger the tube the longer the *time* of producing the vacuum by the air-pump, and hence the greater the waste of power by pumping from a leaking vessel; but by my plan, the large tube will have its vacuum produced *as instantaneously* as the small one, because the velocity of its contents into the vacuum vessel will be the same in either case, and the aperture of discharge will be equal to the diameter of the tube.

The amount of lost power on the present plan is estimated by Barlow at $\frac{1}{2} = 50$ per cent.; now, on my plan the amount of lost power will be limited to that due to the imperfection of the *air-pump alone*, during the interval between the trains, and to half that due to the leakage of the long valve and pipe piston in addition, during the time of transit of a train; so that, for example, upon a line where the engine on the present plan would be one half its time idle; and again, during the time that it would be at work, would be occupied one half of IT in producing the vacuum, and one half in passing the train, which is about Barlow's result for a 9-inch tube three miles long, (and the former, i. e. the production, occupies a *longer* time in a *larger* tube). In this case we should have the lost power for *three-fourths* of the whole time that is alone due to the air-pump; and during the remaining fourth of the whole time the lost power would be that due to the air-pump, plus one half of that due to the tube piston and long valve leakage, or $\frac{1}{2}$ of 50 per cent. $= 25$ per cent. by Barlow's results.

Barlow finds the total lost power $= 50$ per cent., of which four-fifths is due to the long valve and joints, and one-fifth, or 10 per cent. of the whole power is due to the railway tube and air-pump piston. Hence that due to the pump *alone* is overrated at 10 per cent.

But if we suppose the lost power of the air-pump to be 10 per cent., which is greatly above the amount if properly constructed, we have the total lost power $= 10$ per cent. per $\frac{3}{4}$ of the time, and 25 per cent. for $\frac{1}{4}$ of the time, which is equal to an average loss of $13\frac{3}{4}$, say 14 per cent. for the whole time.

Now the capacity of the vacuum vessels is determined chiefly by that which is necessary to produce the required amount of vacuum in the tube on opening communication, and thus permitting equilibrium, or sharing the vacuum between the vessels

and tube, and the amount of engine power required depends upon this magnitude, upon the number of trains passing in a given time, and upon the average amount of leakage as above determined.

Hence, in the case before assumed, the engine power required is that to pass two trains per hour (as Barlow gives 4 trains per hour for 91 horse power working constantly), which on the present plan would require in time,

| | | |
|---|---|---|
| For exhaustion of tube . . . . . | | $5 \times 2 = 10$ minutes |
| For passing trains . . . . . | | $6 \times 2 = 12$ minutes |
| | Total time employed | $= 22$ minutes |

That is, the engine would be 38 minutes in the hour idle, and working for 22 minutes in the hour at a loss of 50 per cent.

Now the engine according to my method must be so proportioned, that working with an average loss of 14 per cent. constantly, it shall be capable in 60 minutes of husbanding a vacuum in the vacuum vessels competent to pass two trains within that time, and still preserve the gauge at its original level in the vacuum vessels at the end of that period.

Let it be assumed that the vacuum in the vessels is maintained at 22 inches of mercury, and that the capacity of the vacuum vessels is = five times that of the railway tube. For this capacity is requisite in order that the vacuum may not vary too much during the transit of the train, and may be sufficiently high in the tube when communication is made, assuming the power of the engine to be competent to discharge the contents of the tube during the passage of the train. The gauge would, by Barlow's results, fall on the average $\frac{1}{2}$ of 4 inches per minute, $= 2$ inches per minute $\times 6$ mins. $= 12$ inches of the gauge during the train's passage, if the leakage was only into the tube; but with a given amount of leakage and a given time the fall of the gauge will be inversely as the capacity of the vessel leaked into; hence, I propose to give the vacuum vessel a capacity five times that of the tube; hence, as the capacity of the tube alone is to that of the tube and vacuum vessel as 1 : 6, the fall of the gauge will be, during the train's transit, only $\frac{12}{6} = 2$ inches.

The capacity of 3 miles of 9-inch tube is $= 6996$, say 7000 cubic feet, five times this, or 35000 cubic feet, must be that of the vacuum vessels.

These being made of boiler plate $\frac{1}{4}$ inch thick may be made 15 feet diameter. 15 feet diameter $= 176.5$ feet square area; the length therefore must be $\frac{35000}{176.5} = 198$ feet; three cylinders, therefore, each 15 feet diameter, and 66 feet long, will provide the requisite space.

With the foregoing dimensions of tube and vacuum vessel and a vacuum of 22 inches established in the latter, on making communication with the railway tube, barometer at 30 inches, we shall have a vacuum common to both of 18.36 inches.

Allowing 24 seconds for equilibrium to take place between the tube and vacuum vessel after opening the valve of communication, and supposing the train to start at that moment, the vacuum gauge will have fallen at the end of the course, or in 6 minutes, 24 seconds, 2.13 inches, or to $18.36-2.13=16.23$ inches, which will be the amount of rarefaction in the vacuum vessels at the moment that the valve is closed.

The engine and air-pump must be competent to restore this vacuum to 22 inches, or to rise the gauge $22-16.23=5.77$ inches during the interval between this and the next train. That is, in 48 minutes divided by $2=24$ minutes, less the time of producing equilibrium between the tube and vessels $=24$ seconds, say in $23\frac{1}{2}$ minutes.

To effect this, as nearly as possible 45 horse power will be required, supposing it only to produce exhaustion between the transits of trains, and merely discharge the pipe during their transit; but as Barlow has shown that 29 horse power is sufficient for the latter, the vacuum will be a little increased by this power of 45 horse power applied to the air-pump during the transit; and hence at the end of the course the gauge will not fall quite so low as above stated, viz. to 16.23 inches. We have thus proved that under the given conditions of a 3-mile line of 9-inch tube, with only two trains per hour, we can dispense by my arrangement with *one half the power assigned as necessary* by Barlow.

---

*Note.*—At 30 horse power air-pump same size as at Wormholt Scrubbs. Capacity $=14.4$ cubic feet, 45 strokes per minute double.

Capacity of vacuum vessels . . . . $=35000$ cubic feet.
Ratio of vacuum vessels to pump . $35000 : 14.4$, or $2430 : 1$.
Ratio of rarefaction therefore . . . . . $\frac{2429}{2430}$.

The number of strokes therefore to exhaust with a perfect pump, the vessels up to 22-inch gauge from common air density, is,

$$N=\frac{\text{log. } 30-\text{log. } 8}{\text{log. } 2430-\text{log. } 2429}=\frac{1.47-0.903}{3.3856-3.3854}=2835 \text{ strokes}^{*}.$$ And to exhaust

[*] The equation $\frac{\delta}{\Delta}=\frac{r_n}{(r+b)^n}$ where $\delta$ is the density in the vacuum vessel after $n$ strokes. $\Delta$ being the original density, $r$ and $b=$the capacities of the vacuum vessel and pump—may take the form

$$\text{Log. } \delta-\text{log. } \Delta=n \text{ log. } r-n \text{ log. } (r+b)$$

and if $\Delta=1$, then

$$\text{Log. } \delta=n\left(\text{log. } r-\text{log. } (r+b)\right)$$

and $$n=\frac{\text{log. } \delta}{\text{log. } r-\text{log. } (r+b)}$$ which is the equation used in the text.

the vessels up to 15.56, say $15\frac{1}{2}$ inches, the number of strokes is,

$$N = \frac{\log. 30 - \log. 14.5}{\log. 2430 - \log. 2429} = \frac{1{\cdot}47 - 1{\cdot}161}{.0002} = 1545 \text{ strokes.}$$ The difference between these gives the number of strokes required to restore the vacuum after the transit of a train.

From which we find that,

30 H. P. will require 63 minutes to exhaust the vessels to 22 inches, and 28 minutes to restore this vacuum after transit of train.

| | | |
|---|---|---|
| 35 H. P. . . . . | 57 minutes to exhaust . | 26 minutes to restore |
| 45 H. P. . . . . | 44 minutes „ „ . | 20 minutes „ „ |

the vacuum, and adding to the latter 10 per cent. for lost power, we learn that 45 H. P. will just meet the demand.

30 H. P. making 45 double strokes per minute.
35 H. P. . . 50 . . . . per minute.
45 H. P. . . 65 . . . . per minute*.

NUMBER OF STROKES REQUISITE TO RAISE THE GAUGE every 2 inches from 6 inches to 24 inches, in case (here taken) of a pump 14.4 cubic feet capacity, vessel 35000 cubic feet, and ratio of rarefaction $\frac{2429}{2430}$. Pump perfect,—common air at 30 inches.

| Height of gauge. | No. of strokes from 30 in. to given height. | 1st difference. |
|---|---|---|
| 24 inches | 3535 | |
| | | 700 |
| 22 „ | 2835 | |
| | | 450 |
| 20 „ | 2385 | |
| | | 395 |
| 18 „ | 1990 | |
| | | 335 |
| 16 „ | 1655 | |
| | | 290 |
| 14 „ | 1365 | |
| | | 255 |
| 12 „ | 1110 | |
| | | 230 |
| 10 „ | 880 | |
| | | 205 |
| 8 „ | 675 | |
| | | 190 |
| 6 „ | 485 | |

The difference in outlay will be as follows, taking the estimates for power given by Samuda.

* Calculated for an excess of power—the fall of gauge is only 5.77 in place of 6.44.—A clerical error.

ON PRESENT PLAN.

| | |
|---|---|
| Engine and air-pump, 91 H. P., complete at £40 per horse-power . | £3,640 |

ON PROPOSED PLAN.

| | |
|---|---|
| Engine and air-pump 45 H. P., at £40 per H. P. . . . . | £1,800 |
| Vacuum vessels and connexions, Wt. 54 tons at £24 . . . . | 1,296 |
| | £3,096 |

| | | | |
|---|---|---|---|
| And the relative cost of working per day will be for 91 horse-power, fuel alone, per day of 12 hours, 10 lbs. per hour per H. P.— at 17*s.* per ton, 4 tons $17\frac{1}{2}$ cwt. . . . . . . . | £4 | 5 | 0 |
| 45 H. P. fuel alone at same rate . . . . . . . | 2 | 2 | 0 |
| Saving per day by the method now proposed . . . . | £2 | 3 | 0 |
| Add interest on capital saved at 8 per cent. . . . . | 0 | 2 | $2\frac{1}{4}$ |
| Total saving per day per station . . . . . . . | £2 | 5 | $2\frac{1}{4}$ |

And in proportion as the number of trains in a given time is less, so will the proportionate saving over the present method be greater.

So also for all greater diameters or lengths of tube, the number of trains being the same in a given time—and with proportionate power and capacity of vacuum vessels will the saving also be proportionate.

In this comparison I have adopted the measure of 10 lbs. per hour per H. P. as the consumption, wishing to take the least sanguine view in favour of my own case, but 12lbs. per hour per H. P. is much nearer the actual consumption of engines worked as would be here required.

The difference in the amount of engine-power required between the two systems, will be less as the number of trains passing in a given time is greater—*but even on a line where the transit of trains is continuous, there will always be an economy of power in favour of my method—equal to 40 per cent. of the lost power during the times of exhaustion, and of 20 per cent. of the lost power during the times of their transit.*

The limit of the number of trains that can be passed in a given time and with a given power (as fixed by Barlow), is that when the whole time of the engine is occupied in exhausting and discharging the tube, and for a 3-mile 9-in. tube

about half the time will be occupied in each such way; but if it be desirable to pass a still greater number of trains, an increase of engine-power will not on the present plan be followed by a proportionate increase of effect. For although the tube will be quicker exhausted, yet during all that portion of time ($=\frac{1}{2}$ the whole) that the train is in transit, the surplus power of the engine will be employed in uselessly raising the gauge *in the tube alone.* But if on the contrary my method be adopted, this surplus power will be usefully absorbed in accumulating vacuum-power in the vacuum vessels, ready to accelerate the exhaustion of the tube for the passage of the succeeding train. *So that by my method a greater number of trains may be passed over a given length of line in a given time, than is possible on the present system even with the engine kept continually at work.*

Hence my method is applicable not only to produce economical working upon a line where the traffic is usually or occasionally small, but also where it is occasionally very great; and this may be further carried out by using two or more coupled engines, to be wrought separately or together.

When the daily traffic on a railway would be very small, say only one or two trains per day, I would still propose to use such a diminutive engine-power as would be only proportionate to the traffic; but it is plain that in such case the engine would be incapable of discharging the leakage of the tube during the train's transit.

This I would provide for by making the capacity of the vessels so great in proportion to that of the tube, that on making communication the fall of the gauge due to leakage would be immaterial; during the transit of a train, even although no engine at all were working, no appreciable loss will arise from this, for however large the vessels be, *once* exhausted, the power expended is so once for all, and all future exhaustion is merely to meet the ingress of air due to traffic.

It is presumed that no practical engineer acquainted with what can be and is daily done in boiler making—will dispute the facility of making large cylindrical vessels of boiler plate, properly stiffened by ribs *absolutely* air-tight, when coated inside and out with a bituminous varnish, or even without such. This seems to be the only question of construction entering into the consideration.

It has been proposed heretofore to husband power and give it out as wanted for these purposes by using the engine-power constantly to elevate water, whose occasional application upon a water-wheel should actuate the air-pump when required.

It is well known that the best over-shot water-wheels ever made have not realised a useful effect of 70 per cent. of the whole power of the fall;—while the average of the best wheels in existence, as made by Fairbairn and others, only gives a useful effect of 60 to 65 per cent. of the power of the fall—even the Turbine or wheel of re-action of Passot is stated only to realise a useful effect of 80 per cent.; hence it is

obvious, that in this method of working from 20 to 40 per cent. of the steam power must be wasted, besides whatever may be necessary to overcome the friction of the heavy pumping apparatus, and of the water in the tubes and pump passages. In this method also the exhaustion of the railway tube is effected out of a constantly leaking vessel; and hence this element of economy in my method is here left unprovided for.

It seems also to follow from what precedes, that much greater lengths of tube may be used between station and station than have been previously contemplated, viz., about three miles, owing to the power that my method gives of exhausting the tube almost instantaneously; especially upon lines of small traffic where the vessels may be large; and on the whole I am clearly of opinion that on all ordinary lines the distances between station and station for power might be extended to at least ten miles by the adoption of my method.

Upon the existing system it is plain that *an uniform* motion of a train can never be obtained, because the engine-power and pump must be competent to discharge the leakage due to the whole length of valve; the force at back of travelling piston is therefore nearly constant; and hence the motion accelerated until the train be brought up by packing up the air before it.

This would be avoided if the exhausting power of the pump could be varied in the same proportion as the leakage, but this is impossible on the existing system. My method, however, gives the power of making the train's motion *quam proxime* uniform throughout its whole transit, for the capacity of the vessel and the power of the pump may be readily so proportioned to the capacity of the tube and the speed of the train, that the air before the piston shall during the whole transit just increase in density inversely as the diminution of leakage; and hence the force at back of piston varying as the time, the motion will be nearly uniform.

Hence it is obvious, that it is not desirable *in any case*, except that of unusual pressure of traffic, to use an engine capable of fully discharging the leakage of the tube during the train's transit.

Should the constant pumping of water ever be used as a means of producing a vacuum, it would seem possible that the most advantageous plan would be to pump it up to more than 34 feet in height, and permit it directly to fill and empty by syphon tubes out of air-tight vessels of suitable capacity, whereby a direct or Torricellian vacuum would be produced which would be perfect, with the deductions for the tension of the vapour of the water due to its temperature, and for whatever small quantity of air might be liberated from it at each filling and emptying.

In summer time, however, this method would be less advantageous, unless water below 70° Fahr. could be commanded, as water boils at about 72° Fahr. in vacuo;

and the tension of its vapour at this temperature is $=0.77$, say about one inch of mercury, or $\frac{1}{30}$.

The height to which the whole volume of water would require to be pumped, would be about 40 feet, and the descent of 34 cubic feet of water $=2125$ lbs. through 20 feet would produce 34 cubic feet of vacuum space, or 42500 lbs., through 1 foot $=34$ cubic feet of vacuum space, of say 28 inches gauge.

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## REPORT II.

EXAMPLE of three miles of nine-inch pipe, worked upon my system, as compared with the present plan, where the engine is one half its time idle; showing the results upon Mr. Bergin's data, as per "his Observations."—8th December, 1842.

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MR. BERGIN'S DATA, PER HIS LETTER, 9TH NOVEMBER, 1842[*].

Vacuum-gauge 18 inches in the railway main.

Total per centage of lost power in producing vacuum = 31 per cent, of which there is due,

| | |
|---|---|
| To air-pump and pipe piston . . . . . . | 10 per cent. |
| To long valve . . . . . . . . . . . | 21 ,, |
| | 31 ,, |

Fall of gauge per minute, average due to leakage, engine at rest, 1.4 inches.
(By average of Bergin's Table this is much more nearly 1.6 inches.)

At 30 miles per hour horse power = 33000 lbs.
Discharging power . . = 23.4 H. P.
Maintaining power for vacuum = 16.2 H. P.
39.6, say 40 horse power.

The maintaining power for vacuum consists of,

Constant, for leakage of pistons . 1.2 H. P.
Variable, for leakage of long valve, 15.0 H. P.
16.2

---

* It may be necessary to state, for those who have not seen Mr. Bergin's "Observations" or Professor Barlow's Report, that he adopts 52,000 lbs., raised 1 foot per minute, as his unit of horse power, while Barlow uses the usual unit of 33,000 lbs., raised the same height in the same time.

Time of obtaining the vacuum of 18 inches gauge $=188$ strokes, at rate of 34.7 strokes per minute $=5' \, 41''$ in time. On my method the amount of lost power will be limited to that due to the imperfection of the *air-pump alone* during the interval between the trains, and to half that due to leakage of long valve and pipe piston, in addition, during the time of transit of a train; so that, for example, upon a line where the engine would *be one half its time idle*, and again, during the half that it would be at work, would be occupied, *one half of it*, in producing the vacuum, and the other half in passing the trains, which is about Bergin's result for a 9-inch tube 3 miles long. In this case we have the lost power for three-fourths of the whole time, that alone due to the air-pump, and during the remaining fourth of the whole time the lost power would be that due to the air-pump, plus one-half of that due to the long valve and piston.

Or, if we assume the lost power of the air-pump $=8$ per cent. (which is above the truth) we have the lost power $=8$ per cent. for $\frac{3}{4}$ths of the time, and 8 per cent. + (half of 21 per cent.) $=18\frac{1}{2}$ per cent. for $\frac{1}{4}$th of the time, which is equal to an average loss of 10.625 per cent. for the whole time; say, 11 per cent. for the whole time.

This separates the total leakage into,

| | | |
|---|---|---|
| For travelling piston . . . . . . | 2 | per cent. |
| For air-pump . . . . . . | 8 | ,, |
| For long valve . . . . . . | 21 | ,, |
| Total | 31 | ,, |

In the case assumed we have the engine at work to pass two trains per hour, or half its time idle.

| | | |
|---|---|---|
| For exhaustion of tube . . . . | $5' \, 41'' \times 2 =$ | $11' \, 22''$ |
| For passing trains . . . . | $6' \times 2$ | $12' \, 0$ |
| Total time employed . . . . . | | $23' \, 22''$ |

Say $23\frac{1}{2}$ minutes; that is, the engine would be $36\frac{1}{2}$ minutes idle, and working $23\frac{1}{2}$ minutes in the hour at a loss of 31 per cent.

Now the engine power, on my method, must be such that working constantly at an average loss of 11 per cent. it shall be capable in 60 minutes of husbanding a vacuum competent to pass two trains, and still preserve the gauge at its original level in the vacuum vessels at the end of that period.

It is still to be investigated what is the best height of gauge to use in the vessels with a given capacity of vessel and tube, and also what is the best proportion between

the capacity of the vessel and tube. If Bergin's data for leakage be correct, the fall of the gauge, during the train's transit, becomes unimportant, and the capacity of the vessels is dependent simply upon the most economic height of gauge in the vessels, as procurable by the pump, and the most desirable pressure on the travelling piston. (See Table V., Bergin's "Observations.")

Assume the vacuum gauge in the vacuum vessels $=22$ inches mercury, their capacity five times that of the railway tube, the power of the engine competent to discharge the tube or nearly so as the train advances. The fall of the gauge being 1.4 inches average per minute, and the time of transit 6 minutes, the total fall $=\frac{6' \times 1.4}{2}=\frac{8.4}{2}$ inches during the train's transit, if the leakage were only into the tube alone.

But as the capacity of the tube is to that of the tube plus the vacuum vessels nearly as 1 : 6, the actual fall of the gauge during this time will be $\frac{4.2}{6}=0.7$ inches.

The capacity of the tube being 7000 cubic feet, and 35000 cubic feet that of the vessel, and a vacuum of 22 inches gauge established in the latter, on making communication, we shall have a vacuum common to both of 18.36 inches gauge. Allowing 24 seconds for equilibrium, and supposing the train to start at this moment, the vacuum gauge will have fallen at the end of the course, or in 6 minutes 24 seconds, $=0.746$ inches, say 0.75 inches, or from 18.36 inches to $18.36-0.75=17.61$ inches, say 17.6, which will be the amount of vacuum at the moment that the valve is again closed.

The engine and air-pump must be competent to restore this vacuum to 22 inches, or to rise the gauge $22-17.60=4.39$ inches, say 4.4 inches during the interval between this and the next train, that is, in $23\frac{1}{2}$ minutes $=(60'-12'\ 48''=47'\ 12''$ and $\frac{47'\ 12''}{2}=23'\ 36'')$.

To effect this 28.94 horse power will be required, supposing it only to produce exhaustion between the passage of the trains, and merely discharge the tube of leakage during their transit. But Bergin states that 23.4 horse power are sufficient for the latter; hence we have always during the time of transit $28.94-23.40=5.54$ horse power employed in raising the gauge, or for $11'\ 22''$ per hour; hence we may deduct from the above 1.3 horse power, leaving the nett horse power required $=27.69$ horse power, say 28 horse power.

*Note.*—At 30 horse power, air-pump same as at Wormholt Scrubbs, capacity $=14.4$ cubic feet, 45 strokes per minute.

Capacity of vacuum vessels . . . . . $=35000$ cubic feet.
Ratio of rarefaction . . . . . . $\frac{2429}{2430}$ „

The number of strokes, therefore, to exhaust, with a perfect pump, the vessels up to 22 inches gauge, from common density, is as before determined (page 12) $=2835$ strokes at 45 per minute $=63'$, and to exhaust them up to 17.6 inches.

$$N=\frac{\log.\ 30-\log.\ 12.4}{\log.\ 2430-\log.\ 2429}=\frac{1.47-1.093}{.0002}=1880 \text{ strokes and } \frac{1880}{45}=41.8, \text{ say } 42$$

minutes; hence the difference, or $63'-42'=21$ minutes, the time required for 30 horse power to raise the gauge from 17.6 inches to 22 inches.

But we have $23\frac{1}{2}$ minutes to do it in; hence the power $=26.8$ horse power, and adding 8 per cent. for pump leakage $=28.94$ horse power. (This is calculated by Barlow's formula, whereas the horse power given as requisite in Bergin's data is by his own formula, which, as giving a smaller result, is unfair to my plans.)

We have thus proved that under the given conditions of a 3-mile line of 9 inch pipe, with only two trains per hour, *we can dispense by my arrangement* with 12 horse power, or *with about one-third of the power assigned as necessary even by Bergin.*

The difference of outlay will be as follows, taking the estimates for outlay for power given by Samuda:—

ON PRESENT PLAN, BERGIN'S ASSIGNMENT OF POWER.

| | |
|---|---|
| Engine and air-pump, 40 H. P., complete at £40 per H. P. | £1,600 |

ON PROPOSED PLAN, SAME DATA.

| | |
|---|---|
| Engine and air-pump, 28 H. P., at £40 per H. P. . . . | £1,120 |
| Vacuum vessels and connexions, W$^{t}$. 54 tons, at £24 . | 1,296 |
| | £2,416 |

Or about one-third more in outlay, assuming Samuda's estimate sufficient,

And the relative cost of working per day will be 40 H. P.

| | | | |
|---|---|---|---|
| fuel alone, per day of 12 hours, 10 lbs. per H. P., at 17*s*. | £1 | 18 | 4 |
| 28 H. P. fuel alone, at same rate . . . . . . | £1 | 5 | 6 |
| Add interest on excess of outlay . . . . . . | 0 | 3 | 6 |
| | £1 | 9 | 0 |

Saving per day $=9s.\ 4d.$ on every three miles of road, or of very nearly $25\frac{1}{2}$ per cent. upon the present expenditure for power upon Bergin's reduced data.

And this ratio of economy will be greater in proportion as the number of trains in a given time are less, and *on the other hand, in the case where the passage of trains is continuous or the engine worked on the existing plan to its full extent of power, there will always be, by my method, an economy amounting to 23 per cent. of the lost power during the time of exhaustion, and of* $10\frac{1}{2}$ *per cent. of the lost power during the transit of trains, the total lost power being now* 31 *per cent.*, according to Bergin.

In a word, whichever set of data be adopted, the principle advocated of exhaustion in a separate and absolutely staunch vessel remains untouched, and all its accruing advantages, economy in power expended, proportionately of this to the work done, and capability of passing a greater number of trains over a given line in a given time and with a given power, than is possible on the existing system, remain in full force, varied only in amount as the conditions of the question are varied.

It may further be remarked, that both in the preceding view and that taken from Barlow's data, an assumption is made very unfair and unfavourable to my method as compared with the existing one. It is assumed that the amount of motive power obtained in both these cases is the same. The gauge is supposed to be raised in the pipe on the existing system of exhaustion to 18 inches, and to continue so, but it is well known now that it cannot remain constant at this during the whole transit. Barlow's experiments would lead us to suppose that it would fall on 3 miles of pipe to below 12 inches gauge at the end of the course, but I will give the whole advantage of an assumed more uniform pressure on the travelling piston to the existing plan, and suppose the gauge to stand at 15 inches at the end. Then we have the average height of gauge during the whole transit of 3 miles on each of the three conditions.

| | | Gauge, inches at commencement. | Gauge, inches at end. | Gauge, inches average. | lbs. per square inch. |
|---|---|---|---|---|---|
| On existing method . | With either data . | 18. | 15. | 16.5 | 8.25 |
| On my method | Barlow's data . | 18.36 | 16.23 | 17.295 | 8.65 |
| | Bergin's data . | 18.36 | 17.61 | 17.985 | 8.99 |

Now in each of these cases there are two trains per hour; I have taken the day at 12 hours $=24$ trains drawn 3 miles per day, and I have estimated the gross expenditure for power in each case, viz.

| | Fuel per day, and difference of interest on outlay. |
|---|---|
| On existing plan. | |
| Barlow's data, 91 horse power . . . . . . | £4 5 0 |
| Bergin's data, 40 horse power . . . . . . | 1 18 4 |
| On my plan. | |
| Barlow's data, 45 horse power . . . . . . | 2 2 0 |
| Bergin's data, 28 horse power . . . . . . | 1 9 0 |

That is, in each case we can draw a gross load $3 \times 24$ miles $= 72$ miles, for the above sums. Hence we obtain for the gross load drawn an expense per mile of,

| | PER TRAIN PER MILE. | | | |
|---|---|---|---|---|
| | Integers and decimals of one penny. | Or, in shillings, pence and decimals. | | |
| On existing plan. | | s. | d. | Decim. |
| Barlow's data . . . . . . | 14.15 | 1 | 2 | 0.6 |
| Bergin's data . . . . . . | 6.13 | 0 | 6 | 0.5 |
| On my plan. | | | | |
| Barlow's data . . . . . . | 7.00 | 0 | 7 | 0 |
| Bergin's data . . . . . . | 4.82 | 0 | $4\frac{3}{4}$ | 0.3 |

The cross section or area of piston of a 9-inch pipe is $9^2 \times .7854 = 63.617$ square inches, say 63 inches; hence from the first Table we get the following average piston pressures for each plan upon the data taken.

Existing plan . . . . . . . . . . 519.75 lbs.
My plan.
Barlow's data . . . . . . . . . . 544.95
Bergin's data . . . . . . . . . . 566.37

Now, strictly, *the gross load capable of being moved upon each plan is that due to the minimum pressure upon the travelling piston ;* here again, however, I give the advantage to the existing method, which has the lowest minimum pressure, and deduce the gross loads in each case from the average pressure, thus:—

On existing plan, either data . . . . . . 46.4 gross load.
On my plan { Barlow's data . . . . . . 48.6 ,,
On my plan { Bergin's data . . . . . . 50.6 ,,

Allowing the traction : load :: 1 : 200.

If the gross load were taken from the minimum in both cases, in place of the average pressures, the result would be much more favourable to my method.

And hence, finally, we get the following values for the cost of transit per ton per mile in each of the four cases.

| | Transit per ton per mile. |
|---|---|
| On existing plan. | |
| Barlow's data . . . . . . . . | 0.305 of a penny. |
| Bergin's data . . . . . . . . | 0.132 „ |
| On my plan. | |
| Barlow's data . . . . . . . . | 0.144 „ |
| Bergin's data . . . . . . . . | 0.095 „ |

Or in round numbers, the value of my plan, as compared with the existing one in the given case, is—

On Barlow's data, as 30 : 14, or say 2 to 1.

On Bergin's data, as 13 : 9, or say $1\frac{1}{2}$ to 1.

Taking into consideration both the load drawn and the cost of drawing it.

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## SOME ADDITIONAL OBSERVATIONS.

I proceed to consider the effects of my system applied upon a railway where there would be only four trains per day, viz., two in each direction, which would probably be the amount of traffic upon some Irish railways of great length; assume as before one station of 3 miles of 9-inch pipe, and that the engine only works 12 hours per day: we have $4 \times 6$ min. $= 24$ min. in the day occupied in passing trains, and 11 hours 36 minutes of idle time for the engine. Suppose the same capacity of vacuum vessel, and same heights of gauge as before, then we have $\frac{11 \text{ hrs. } 36 \text{ min.}}{4}$ $=$ 2 hours 54 minutes less 24 seconds, say 2 hours $53\frac{1}{3}$ minutes, to restore the vacuum from 17.6 inches to 22 inches, or to raise the gauge 4.4 inches; but we found that 29 horse power would do this in $23\frac{1}{2}$ minutes; hence we get $\frac{23 \text{ min. } 5 \times 29 \text{ horse power}}{173.5 \text{ min.}}$ $= 3.9$ horse power, which will be sufficient to restore the vacuum in this time. But according to Bergin, 23.4 horse power is required for discharging the pipes as the train advances, and according to his data for leakage the gauge would fall during one transit, if the pump ceased to work, 0.7 inches. This discharging power is not needed, owing to the great capacity of the vacuum vessel.

We must therefore add as much more power as will restore the leakage only between the passage of two trains. Less than one horse power will do this; hence, taking whole numbers, we have five horse power as the total of that required.

The relative outlay for three miles, therefore, will be, Bergin's data:—

| | | |
|---|---|---|
| On existing plan, 40 H. P. engine complete, at £40 . | | £1,600 0 0 |
| On my plan, 5 H. P. engine at £40 . | £200 0 0 | |
| Vacuum vessels as before . . . . | 1,296 0 0 | |
| | | £1,496 0 0 |
| Saving in outlay, on my plan . . . . . . | | 104 0 0 |

And the relative cost of working per day will be—

| | |
|---|---|
| On existing plan, 40 horse power for 12 hours as before, for as the engine is required once every 3 hours, steam must be up all day . . . . . . . . . | £1 18 4 |
| On my plan, 5 horse power on same consumption, or a little more, say $5\frac{1}{2}$ cwt. at 1*s.* 5*d.* . . . . . . | 0 7 $9\frac{1}{2}$ |

From which I would have a right to deduct 8 per cent. on £104 for saving in outlay. The difference in cost of working per day is, therefore, £1 10*s.* $6\frac{1}{2}$*d.*, in favour of my plan, or a saving of about 80 per cent. upon the cost of working by the existing mode. Or if it be assumed that, by any possible contrivance, steam could be kept up and the work done with the 40 horse power, and *one half of the fuel* saved, there still would be a saving of 40 per cent. in favour of my plan.

But even this is, perhaps, not the most important view suggested by the consideration of this particular case, viz., of a line of railway of considerable length and small amount of traffic,—a case certain to be realized in Ireland, and in very many other countries in which railways may yet be introduced.

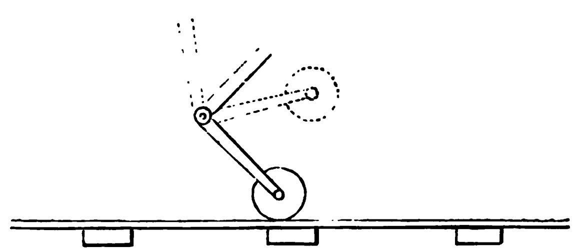
It is well known that there are comparatively very few places (perhaps it might be said none, in which a railway can be formed) on the face of temperate countries, in which, either by natural or artificial drainage, such diminutive rills of water may not be found, at every three or six miles distance, as would fully suffice to actuate water-wheels giving out the very small amount of water power required on my method, without the necessity of constructing either those large and expensive wheels, or extensive and costly reservoirs, indispensable upon the existing one, if steam be abandoned, and which in most countries are not possible to be obtained.

It has been noticed by Dr. Robinson, that my method greatly reduces the power of stopping a train in motion by the means proposed by the patentees of opening a valve in the back of the travelling piston, inasmuch as the vacuum space is so much increased by my plan as to take a long time to destroy the vacuum in this way.

This method of retardation depends upon two simultaneous effects due to

opening this piston valve, namely, reducing the surface of piston pressed, and reducing the amount of pressure upon its remaining surface. The first remains untouched by my plan, and the latter, it appears to me, may by a simple arrangement be so too; or rather, by what I am about to propose, this power of retarding the velocity of a train in motion may be greatly increased above what it is on the existing method, or on any heretofore proposed.

I would place between the valve which closes communication of the railway tube and vacuum vessel a second valve,—a double-seated hanging valve, maintained always open, but capable of falling on a detent being released, and of instantly closing the communication between the railway tube and vessel. A strip of sheet copper, $\frac{3}{4}$ of an inch wide, should run continuously, parallel with the rails, and between them, sustained by a narrow board on the cross-sleepers; and a metallic roller with an amalgamated face of 2 inches wide, attached to the leading carriage, is contrived so as to be capable at any moment of being brought into contact with this strip, thus:—



By this means a galvanic circuit may be instantly completed at the leading carriage, at a point *anywhere along the line*, including in it the before-mentioned valve; the circuit being through the rails, or pipe and leading carriage, and back through the strip of copper. Hence, by a simple magneto-telegraphic arrangement this valve may be dropped by releasing a detent, and all communication closed between the vacuum vessel and railway, the moment contact is made, by pressing the roller against the strip of copper with a lever, which should be done by connection with the machinery which opens the valve in the back of the piston.

But further, I propose to connect with this falling valve at the vacuum vessel a second valve, opening into the railway tube and communicating freely with the air, and so arranged that at the same moment the stop-valve is dropped, or closed, this valve should open and admit the air to the railway tube; so that in place of the air-pump continuing at work, and the air entering the vacuum of the railway tube only through the valve in the back of the piston, as heretofore proposed, by my plan all further *cause* of vacuum is cut off, and air admitted at *both ends* of the tube at one

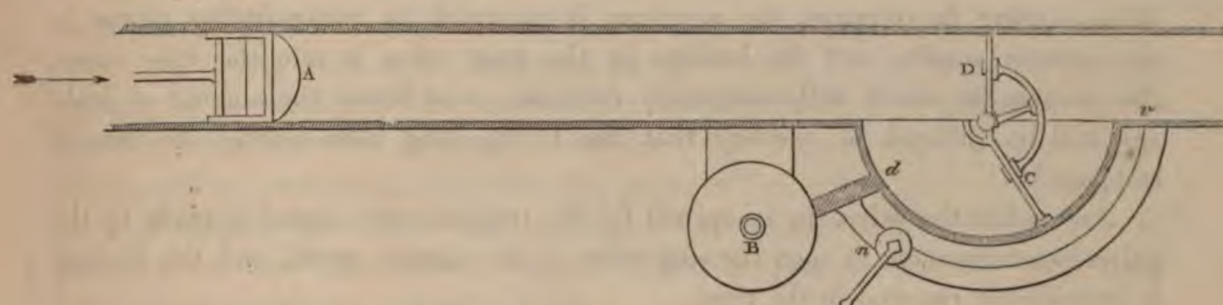
and the same instant, and at one end by an aperture equal to the *full diameter* of the pipe.

At present (so far as I know) the only method proposed for stopping at stations, or anywhere else between the ends of the tube, is by means of the brake; the disadvantages of which seem to be, the uncertainty of stopping at all when the rails are slippery, the uncertainty at all times of stopping at a given point, the constant and dangerous tendency to motion in the train while at rest, and the loss of power by leakage during whatever time the train may be detained at a station.

This loss will be the whole of that due to the long valve, travelling piston and air-pump, during the time of stoppage.

Now, by a further adoption of the arrangement just described, in combination with a modification of the entrance valve, I propose to make the stoppage of the train certain, at any given point, and under the complete control of the conductor; and further, to reduce the entire loss by leakage, during the time of its stoppage, to one half that due to the long valve for the exhausted portion of the tube; saving thus the whole of the travelling piston leakage, and all that due to the air-pump.

This I effect by placing just in advance of the stopping place an entrance valve, so arranged that on pressing the before-mentioned roller upon the copper slip, and so making contact, or by the direct action of the train in dropping a weight, a valve, B, shall be released and admit air behind the equilibrium valve, C, and at the same instant admit air into all that portion of the pipe between the valve, D, and the travelling piston.




Now in the pipe at A there will be air at—say 30 inches, and the same behind the valve C at A, and a vacuum of, say 18 inches, at V. Hence the valve D would open with any force, however slight, if D and C were of equal area; C must therefore be rather larger in area than D, for steadiness merely.

The moment the valve has got into the position in the figure, it is caught by a strong detent at the spindle, or centre of motion, which holds it fast until released. The travelling piston continuing to advance, packs up the air admitted by the valve, B,

before it; but this is so constructed, by a simple hanging flap valve next the tube, that as soon as any pressure outward is thus produced it closes itself, and hence the further advance of the train is brought up, and finally brought to rest by the elasticity of the air now included in the tube between the piston and the valve, D, or, in other words, by a powerful air buffer. In order that this effect may take place, it is obviously requisite that some yards of the long valve just in advance of the train, or behind the valve, D, shall be held down to a certain extent as the travelling piston packs the air and so prevents its escape. This I would effect by making this part of it much heavier than the rest, or by a series of jointed detents which move across the long valve at the moment the valve, D, closes, and are moved by its motion. These prevent the rising of the long valve until the train is to start, when the opening of the valve, D, again leaves the valve free.

When the train is again to start, the small cock, N, is turned by hand, (by the station keeper,) and the space, A, behind the valve, C, becomes instantly exhausted from the pipe at V, and hence the valve, D, opens the moment the detent upon its spindle is released, which is also done by the same motion; the pipe at A is again exhausted, and the train starts.

So far, it will be admitted that by this arrangement the leakage of the travelling piston is saved during the train's stoppage. But in addition, the valve, B, is so connected with the stop-valve, at the vacuum vessel before spoken of, that the moment B opens the stop-valve closes, and hence communication is cut off between the vessel and railway tube at the moment that the train stops. Thus, during its stoppage, the air-pump is occupied in accumulating power in the vacuum vessels, and the leakage by the long valve is into the tube alone, the vacuum in which will continually decrease; and hence the amount of leakage will be reduced to *one-half* that due to the long valve during the time of stoppage [a].

Just before the valve, D, is opened for the train to start, signal is made by the galvanic arrangement to open the stop-valve at the vacuum vessel, and the vacuum is immediately restored in the pipe.

It is obvious that this arrangement for stopping at stations may be carried through without any galvanic arrangement whatever beyond that of the common galvanic telegraph, or, abandoning the saving of half the leakage of the long valve, without even the need of this.

[a] This is perhaps not quite correct, as it has been found, since these Reports were written, that the leakage is not exactly in the ratio of the height of the vacuum guage, but less in proportion for good than bad vacuums, arising from the former bringing the long valve better home to its seat.—R. M.

It is also apparent that this arrangement would have the advantage of making the persons at the seat of power aware of every stoppage along their own section of the line, and hence, of any accident taking place, or any delay of trains, &c., all of which are sources of safety.

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## REPORT III.

### ON THE MEANS OF PRODUCING VACUUM FOR THE ATMOSPHERIC RAILWAY BY THE DIRECT ACTION OF STEAM.

#### WITH AN EXAMPLE OF SIX MILES OF RAILWAY MAIN EXHAUSTED IN ONE LENGTH.

(15th Nov. 1842.)

In the case of vacuum procured for locomotive purposes by means of an air-pump wrought by a steam-engine, it is plain that the engine can only be considered as a primary machine to produce a vacuum, the power resulting from which is again transferred to a second machine, the air-pump, whose function it is to reproduce the vacuum, whose resulting power is to be applied to effect locomotion.

Hence, of the power of the coal, or theoretical power of the steam, there must be lost, that due to work these two complex machines themselves. The residue can alone be that available for locomotion.

It therefore would appear, that if the generation and condensation of steam in close vessels of suitable capacity could be conveniently effected, its whole theoretic power with some very small deductions would be directly available in producing vacuum for locomotion. But besides this very general view, important practical considerations, especially relating to the conditions of working the atmospheric railway system, seem to be involved in the latter mode of obtaining the vacuum.

It is admittedly of great value to be able to use the longest possible lengths of tube between station and station, and to be able to procure a vacuum in the largest length of tube with the greatest rapidity.

On the existing method, any increased length of tube, or rapidity of exhaustion, can only be obtained by a proportional augmentation in the capacity of the air-pump, and an equally proportionate increase of steam power; but as no means are as yet provided for using this power to advantage between the times of trains, and as steam must be always up in the engine boilers, any increase in the rapidity of exhaustion must be attended with a proportionate loss of fuel, beyond that only necessary to meet the increased demand for power.

Now in further considering this new mode of producing vacuum by the direct application of steam, it will appear :—

1st. That greater lengths of tube may be more rapidly exhausted than would probably be ever proposed to be attempted with the air-pump alone.

2nd. That such lengths of tube may be exhausted to a sufficient degree with great rapidity, and the tube discharged as the train advances.

3rd. That an economy of power, or in fuel, will result.

4th. That the apparatus may be so arranged that the whole of the steam generated between the trains shall be made available to produce vacuum.

5th. That the required apparatus will be more simple, and subject to less wear and tear, than an engine and air-pump of equal power, and certainly not more costly in original outlay.

6th. That this method admits of combination with my other proposal for "storing the vacuum," so as to economize the whole power wasted between trains upon the present system.

We will first, then, briefly describe the apparatus proposed being used, as designed for six miles of fifteen-inch tube. This consists generally of a system of boilers to generate steam, arranged upon a modification of the Cornish construction, and with peculiar adaptations for withdrawing the fires when steam is not demanded. Of two sets of vessels wherein the vacuum is produced, and which I call "vacuum vessels," each consisting of two cylinders. And lastly, of a third vessel, called the condensor, in which the steam which has been generated in the boilers, and been blown into the vacuum vessels, expelling the air therefrom, is condensed, leaving them vacuous.

The boilers are six in number, five are required to be in action at once, leaving one for cleaning; each of these is cylindrical, on the Cornish plan, but with a fire-place at each end. The flues meeting in the centre of the length, and with a large super-imposed steam-chest, to contain a sufficient volume of steam to fill the vacuum vessels alternately with rapidity. Steam is to be produced in these boilers at 45 lbs. per square inch, above the atmosphere, and will blow off into the vacuum vessels, down to low pressure, or almost to atmospheric pressure.

The construction of the boilers is such as to admit of the withdrawal of the fires from beneath all those in use, by a simultaneous movement, into a brick arched vault or cavity, the supply of air and the chimney dampers being shut off by the same movement. The air within the cavity and boiler flues is thus almost immediately exhausted by the fires of its oxygen, and replaced by carbonic oxide and acid gases and various inflammable products of the coal. The fuel thus ceases to burn, but

remains hot, and smouldering, until again steam is wanted; when the fires are passed in under the boilers, air is re-admitted, the inflammable gases in the flues in part take fire, and are consumed, or pass off, and the vigorous combustion of the fuel is recommenced.

The radiated heat of the fire, which had previously been absorbed by the brick-work of the arch of the cavity is now carried off by the stream of cold air into the boiler flues, and becomes available, and thus no part of the fuel is lost at any period of the operation. This improvement is obviously applicable to boilers of any sort when intermittingly employed for any other purpose, as well as on the present system of the atmospheric railway.

The proportions of these boilers are taken from those of the best Cornish examples, and are calculated to boil off, from a temperature of 70° Fahrenheit, rather more than four cubic feet of water per minute into steam, at 45 lbs. per square inch above the atmosphere, five of the boilers being at work; and to perform this, with a consumption of not more than 5.9 lbs. avoirdupois of good coal for each cubic foot of water so evaporated.

The boilers are jacketed as in Cornwall; the feed water passes into a large pipe placed in the last flue, (next the stack,) and acquires there a temperature of nearly 212° Fahrenheit before it enters the boilers.

A main steam-pipe, connected with all these boilers by stop-valves, unites with two branches by which steam is brought to the vacuum vessels and condensor.

The vacuum vessels are two in number, and are to act alternately; each consists of two cylinders of boiler plate, stiffened by ribs on the outside, jacketed with saw dust and sifted ashes outside, and lined with staves of pine three inches thick throughout the interior, as shown at large on the plans; the construction of the shell of the condensor is precisely similar, and its capacity is equal to that of one of the vacuum vessel cylinders. That is, the capacity of the condensor is one half that of one vacuum vessel.

The two cylinders forming each vacuum vessel are in free communication, and the only reason of using two cylinders in place of one, is, that a much larger diameter would be in danger of compression, unless stiffened at great cost; and a much greater length would be inconvenient. The capacity of the vacuum vessels is determined by that of the tube to be exhausted.

Between each of the vacuum vessels and the condensor are placed three double beat valves, (or six valves in all); the functions of one of them with reference to each vacuum vessel is to admit steam thereto alternately, and shut it off; of another, to

establish or close alternately communication between the vacuum vessels and condensor; and of the third, to establish and close alternately communication between the vacuum vessels and railway tube.

The object of lining both the vacuum vessels and condensor with wood (a bad conductor of heat) is, that the former being alternately filled with steam and with air at common temperature, and the latter having nearly a constant rush of steam into it to be condensed, it is desirable that the inner surfaces of these vessels should be in a condition neither to receive nor to give out heat; or in other words, to change temperature as little as possible, all such change being in the case of the vacuum vessels attended with waste of steam, and of the condensor with waste of condensing water.

Condensing water is supplied to the condensor by a perforated pipe and stop valve, from a reservoir or source with a head of four or five feet of water.

The condensing water and condensed steam are removed from the condensor, and the condensed steam that may form in the vacuum vessels, by means of inverted syphon pipes, with a balance valve at the lower end, and having a total difference of level between this point and the lowest part of the vacuum vessels or condensor of 34 feet.

The only remaining valves are the "snifting valves," or large balanced valves at the ends of the vacuum vessels to give egress to the air on admitting steam, and similar but smaller ones to the condensor.

These latter valves are self-acting. The six former valves spoken of, viz., the three belonging to each vacuum vessel, are moved either by hand, or by a motion derived from suitably formed "cams," actuated by the same very small steam engine which is required to feed the boilers with water.

It is proposed to condense the steam, so that the condensing water shall flow off at 70° Fahrenheit; at this temperature such quantity of it as is required is withdrawn by the feed pumps from the well at the lower end of the condensor syphon, and pumped into the hot water tube in the boiler flue before spoken of.

This constitutes the whole apparatus, its operation is as follows:—

Steam being up in the boilers, a little is blown off into the condensor, and the stop-valve shut; the condensing water is admitted, and a very slight vacuum is produced in the condensor. This is requisite to cause the steam from the first vacuum vessel to enter the condensor rapidly, when permitted. The steam valve is now opened to one vacuum vessel, say the left-hand one, the other two valves, viz., the condensor and railway valves, being shut. The air is expelled from it by the snifting

valves, and as soon as steam "blows through", the valve from the boiler is shut, and the condensor valve opened; the contents of the vacuum vessel now rush into the condensor, and are condensed. The valve between the vacuum vessel and condensor is now shut, and that between the former and railway tube opened, when air from the latter rushes into the partial vacuum of the vessel.

The moment the steam valve was shut to the left-hand vessel, it was opened to the right-hand one, which in the same way was filled, and by a precisely similar set of operations a partial vacuum was formed in it, and communication made between it and the railway tube just subsequent to the moment when communication was closed between it and the former vessel, and so on alternately, each vessel being filled with steam; this condensed, a vacuum produced, and air admitted therein from the railway tube until in equilibrium.

These actions recur at regular intervals, and the cams moving with a uniform motion, are so arranged as to open and close the several valves at the proper times.

These times and the general working of the machine, which is much more simple than it seems in words, are best seen by inspecting the following diagram or expression in signs of the whole motions.

It will thus be observed that each of the vacuum vessels is alternately engaged in exhausting the railway tube and in forming its own vacuum. The valves are at the first moment moved by hand, and afterwards uniformly by the engine, which is worked by the same steam boilers as are employed in the apparatus at large.

## WORKING OF THE VACUUM APPARATUS.

| Section of Apparatus. | | Left Hand Vacuum Vessel Plenum. | | Condensor partial Vacuum. | | | Right Hand Vacuum Vessel Vacuum. | | |
|---|---|---|---|---|---|---|---|---|---|
| Piece Moved. | | Railway Valve. | Steam Valve. | Left Vacuum Valve. | Condensing Water Valve. | Right Vacuum Valve. | Steam Valve. | Railway Valve. | |
| Time. | Change. | | | | | | | | Change. |
| 0 min. | • | Shut. | Open. | Shut. | Shut. | Shut. | Shut. | Open. | •Exhausting• |
| 30″. | | | Shut. | Open. Shut. | Open. | | Open. | Shut. | |
| | •Exhausting• | Open. | | | | | | | |
| 1 min. | | Shut. | Open. | | | Open. Shut. | Shut. | Open. | |
| 30″. | | | | | | | | | •Exhausting• |
| 2 min. | | Open. | Shut. | Open. Shut. | | | Open. | Shut. | |
| 30″. | •Exhausting• | Shut. | Open. | | | Open. Shut. | Shut. | Open. | |
| 3 min. | | | | | | | | | •Exhausting• |
| 30″. | | Open. | Shut. | Open. Shut. | Constantly open while at work. | | Open. | Shut. | |
| 4 min. | •Exhausting• | Shut. | Open. | | | Open. Shut. | Shut. | Open. | |
| 30″. | | Open. | Shut. | Open. Shut. | | | Open. | Shut. | •Exhausting• |
| 5 min. | •Exhausting• | Shut. | Open. | | | Open. Shut. | Shut. | Open. | |
| 30″. | | | | | | | | | •Exhausting• |
| 6 min. | •Exhausting• | Open. | Shut. | Open. Shut. | | | Open. | Shut. | |
| 30″. | | Shut. | Open. | | | Open. Shut. | Shut. | Open. | • |
| 7 min. | | | | | | | | | |

Note.—To make this table completely intelligible, the reader should rule lines across at intervals of ten seconds.

We have next to consider the proportions of the various parts of the apparatus. Let us suppose as applicable to a length of six miles of 15-inch pipe.

The capacity of the tube is $\overset{\text{ft.}}{5280} \times 6 \times \overset{\text{sq. ft.}}{1.227} = 38872$ cubic feet.

The capacity of each condensing vessel we will assume to be one half this $= 19436$ cubic feet. And as each consists of two cylinders—

$$\frac{19436}{2} = 9718 \text{ cubic feet, capacity of one.}$$

These cylinders may be made of 10 feet diameter $= 78.54$ square feet area:

$$\text{Hence the length} = \frac{9718}{78.54} = 124 \text{ feet.}$$

The capacity of the condensor need not be more than one half that of either condensing vessel, for such a proportion has been found to give sufficiently rapid condensation in large steam-engines, and the same must hold here. Hence the condensor will be one cylinder of 10 feet diameter and 124 feet long.

The dimensions of the boilers are dependent upon the supply of steam demanded per minute.

We shall presently see that a sufficient vacuum for starting will be produced in a 15-inch pipe of six miles long, by three exhaustions of one vacuum vessel, and that three to four more exhaustions will discharge the tube as the train advances. Now if the speed of the train be 30 miles per hour, 6 miles will be passed over in 12 minutes, which gives an interval of 3 minutes between each exhaustion. This is the limit therefore for the supply of steam. We must have as much steam as will blow the air out of and fill one vacuum vessel every three minutes at 212° Fah., or the power of this in the boilers. But for the more rapid and effectual blowing through of the vacuum vessels, as well as to save boiler room, it is proposed to generate steam in the boilers at 3 atmospheres $= 45$ lbs. above the atmospheric pressure. Hence required $\frac{1}{3}$ the full of one vacuum vessel of dense steam at 45 lbs per three minutes, Now allowing $\frac{1}{10}$th of the volume of steam to be lost, which we shall hereafter show to be an ample allowance, we require every three minutes $19436 + \frac{19436}{10} = 21379$ cubic feet of steam at 212° Fah., which again is about equal to $\frac{21379}{3} = 7130$ cubic feet of steam at 45 lbs. per square inch, and $\frac{7130}{3} = 2376$ cubic feet of steam at same pressure is that required in one minute.

Now steam at this pressure gives about 620 volumes from one of water, hence $620 : 1 :: 2376 : 3.83 =$ cubic feet of water required to be evaporated per minute;—

say four cubic feet per minute. Hence we get the following dimensions for the boilers, supposing those of the Cornish principle adopted. If locomotive boilers be used, four boilers of the common large size would be sufficient; but then the consumption of fuel per cubic foot of water evaporated would rise from 5.9 lbs. of coal to about 11.0 or 11.5 lbs. of coke.

Steam being generated at 45 lbs. in the boilers we must, (in order to obtain a rapid rush of steam into the vacuum vessels, and so discharge them of air with certainty,) not calculate upon the *continual* supply of steam, but provide a steam space in the boilers of rather more than one third the capacity of one vacuum vessel, so that on opening the steam-valve they can be blown off at once into the vacuum vessel; allowing then, as before, $\frac{1}{10}$th of steam for waste, we have $\frac{21379}{3} = 7130$ cubic feet for the requisite steam space.

The results of experience in Cornish boilers prove that five boilers, each 6 feet 6 inches diameter, by 110 feet long, with a fire grate surface of 72 square feet each, in two fire places, one at each end of each boiler, will generate the required volume of steam, consuming 5.9 lbs. of coal per cubic foot of water evaporated from 70° Fah. into steam at 45 lbs. per square inch.

These five boilers will possess a steam space of 3500 cubic feet. The remainder of that required, viz. 3630, must be provided by steam chests placed upon the boilers.

Let us next consider if the allowance of $\frac{1}{10}$th of the whole volume of steam for waste is sufficient, which is 1943, say 2000, cubic feet of steam at each filling of the vacuum vessels; the sources of waste steam are:—

1. Cooling by radiation from the pipes and vacuum vessels.
2. Heating the cold air entering the vacuum vessels from the railway tube.
3. Blowing off at safety valves of boilers.
4. Leakage and blowing through at snifting valves.

The two last can only be guessed at; the first and second may be calculated approximately.

The surface of one pair of vacuum vessel cylinders = 2 cylinders of iron, 10 feet 6 inches diameter, by 124 feet long, assumed half an inch thick, which is double their proposed scantling, and adding as usual $\frac{1}{10}$th for angle and rivet iron.

10.5 diameter area of end = 87 square feet.
Circumference . . . = 33 ,, ,,
Hence, area of 4 ends = 348 square feet.
Cylinder surfaces = 124 × 33 × 2 = 9184 ,, ,,

9532 square feet.

Which at 20 lbs. per square foot, and adding $\frac{1}{10}$th, is $= 209704$ lbs.; and as a cubic foot of wrought iron weighs 477 lbs. $\frac{209704}{477} = 417$ cubic feet of iron. But .0051 lbs. of coal will heat 1 cubic foot of iron 1° of Fahr. And assuming the utmost possible waste, or that the whole mass of iron representing the vacuum vessel were heated at first starting from 50° to 200° or 150° Fahr., then 0.765 lbs. of coal will heat 1 cubic foot of iron 150°, and hence $417 \times 0.765 = 319$ lbs. of coal.

But from the construction of these vessels no more than a thin film of pine timber of the lining will be heated to 212° at each filling with steam, so that probably the $\frac{1}{100}$th of the above, or the loss of 3 lbs. of coal, will be the outside of the waste at each filling with steam by cooling from the vessel itself. Now 3 lbs. of coal is represented by 607 cubic feet of steam at 212°. But we have a further loss of heat in the air which, entering the vacuum vessel at each period or stroke, (as we shall call each filling with steam and condensation thereof,) must be heated by radiation from the vessel, and by the next entering steam from the mean temperature 50° to say 200° = 150° Fahr.

The vacuum vessel holds 19436 cubic feet; let us assume this whole volume of air heated 150° at the first stroke, half of it at the second, and half of that at the third, &c.

Now .00000184 lbs. of coal will heat 1 cubic foot of air 1 degree Fahr., hence .000276 lbs. of coal to heat 1 cubic foot 150°; and $.000276 \times 19436 = 5.364$ lbs. of coal to heat the whole volume at the first stroke 150°; half this, or 2.682 lbs. for the second, and half that for the third, &c.; but suppose the waste of the first stroke to continue all through, on the previous data, 5.364 lbs. of coal = 1092 cubic feet of steam. So that it appears, after the apparatus is got to work, that 1699 cubic feet of steam is more than enough to meet the principal sources of waste, leaving 301 cubic feet of steam at each stroke for leakage and blowing through. Hence our allowance of $\frac{1}{10}$th the whole volume for waste is ample.

We have next to consider what amount of vacuum we can obtain by a given number of exhaustions of the vacuum vessels and equilibrations with the air in the railway tube. It is obvious that a vacuum-producing apparatus of this sort may be considered as an air-pump, in which the railway tube is the receiver $= r$, and the vacuum vessel the barrel of the air-pump $= b$; and that if the condensation of the steam give a perfect vacuum, the usual formula,

$$\frac{r^n}{(b+r)}d$$

would represent the amount of rarefaction after $n$ exhaustions, and that we may so consider the present case, applying to the results obtained suitable corrections for the three following sources of deduction from the amount of vacuum, viz.:—

1. For the tension of aqueous vapour due to the temperature of condensation, this being determined at 70° Fah., is $=0.726$ inches of mercury. This amount of deduction for vapour is too great, for the limit of tension of vapour will be, after a few seconds, that due to the *coolest* part of the apparatus; but this is the railway tube, which is always in connexion with one vacuum vessel; and as the temperature in this would probably never be above 60°, and its average below 50°, the real tension of vapour to be calculated on would be due to those temperatures.

2. For the volume of combined air liberated from the condensing water, and carried in by the steam. Rain water contains from $2\frac{1}{2}$ to 3 per cent., say 5 cubic feet of air for every 100 feet of water introduced to the condensor.

3. For the expansion of the air from the railway tube entering the vacuum vessels and becoming heated, and hence practically *less* entering at each stroke than is due to the capacity of the vessel and difference of pressure. Air expands $\frac{1}{480}$ of its volume for 1 degree Fahr., or more correctly according to Rudberg $\frac{1}{493}$; but take the larger expansion, and assume that the air entering the vacuum vessels from the tube gains 20° Fahr., then $\frac{20}{480}=$ its expansion $=\frac{1}{24}$. But the effect of this is tantamount to diminishing the capacity of the vacuum vessel, or the value of $b$ $\frac{1}{24}$ part; so that if the capacity of the railway tube be in this case represented by 200, that of the vacuum vessel will be $=$ say $100-(\frac{1}{24}$ say $\frac{1}{5})=95$. To this another small correction should be made for the air of the railway tube becoming saturated with vapour on entering the vacuum vessel; this may however be neglected.

In order to obtain the value of our second correction, we must now determine the volume of condensing water required for each stroke or period. We have already found that 7130 cubic feet of steam at 212° Fah. is required to be condensed per minute. Let

$L=$ the sum of the latent and sensible heat of steam at the given temperature $=1212°$.

$t=$ the temperature of the condensing water.

$T=$ its temperature after condensation.

$c=$ the cubic feet of steam.

Then $\frac{L-T}{T-t} \times C = Q$, the volume of condensing water at the temperature $t$, in cubic inches.

The volume of condensing water, therefore, required for one stroke or period, at the following temperatures, is

| Temperature. | Cubic feet per min. | Cubic ft. for 1 stroke, or in 3 min. |
|---|---|---|
| 50° Fahr. | 235 | 705 |
| 40° | 151 | 453 |
| 32° | 120 | 360 |

And as each 100 cubic feet of water is supposed to involve 5 cubic feet of air, there will be evolved in one stroke or period, at

| | |
|---|---|
| 50° Fahr. | 35.25 cubic feet |
| 40° | 22.15 ,, |
| 32° | 17.80 ,, |

This air we may suppose introduced to the vacuum vessel dry, and as it will become saturated with vapour at 70°, from the moist sides of the vessel, its bulk will be enlarged; but inasmuch as we have taken 5 per cent. in place of $2\frac{1}{2}$ or 3 per cent. for the air evolved, and as in most cases the condensing water will not even contain this much, and may be used over again, and so evolve scarcely any, it is not worth while to apply this correction. Hence, taking the nearest whole numbers above the preceding, and as the evolved air will always occupy one vacuum vessel and the condensor together, whose united capacity is $= 29154$ cubic feet, we have at the first stroke, and with the above temperatures of condensing water, the following values for the air evolved in terms of the vessels' capacity:—

50° Fahr. . . . . . $\frac{29154}{36} = \frac{1}{809}$

40° ,, . . . . . . $\frac{29154}{23} = \frac{1}{1267}$

32° ,, . . . . . . $\frac{29154}{18} = \frac{1}{1619}$.

The amount of vacuum, therefore, will be diminished by this amount at the first stroke, and $n$ times this for $n$ strokes; and taking 30 inches to represent the whole vacuum, we get the following table of the amount of deduction due to evolved air at each of the first eight strokes for the three above given temperatures of condensing water.

| Strokes. | Temperature 50°. Inches of mercury. | Temperature 40°. Inches of mercury. | Temperature 32°. Inches of mercury. |
|---|---|---|---|
| 1 | 0.037 | 0.0237 | 0.0185 |
| 2 | 0.074 | 0.0474 | 0.0370 |
| 3 | 0.111 | 0.0711 | 0.0555 |
| 4 | 0.148 | 0.0984 | 0.0740 |
| 5 | 0.185 | 0.1185 | 0.0925 |
| 6 | 0.222 | 0.1422 | 0.1110 |
| 7 | 0.259 | 0.1659 | 0.1295 |
| 8 | 0.296 | 0.1896 | 0.1480 |

It thus appears, where the capacity of the vessels is so large, that up to the eighth stroke this correction is quite unimportant, even with condensing water at 50° Fahr., and supposing the whole of the air evolved to remain in the vessels. But, as at each succeeding stroke the vacuum vessels are filled with steam, *two-thirds* of the whole quantity of air evolved from the condensed water of the preceding stroke is blown out; and hence the actual depressions of the vacuum gauge would only be one-third of the values in the preceding table, or insensible until after about 80 strokes, when the condensor itself would have to be cleared of air by blowing through.

And thus it appears that the larger the vacuum vessels can be made in capacity the better; the limit of size being wholly dependent upon practical considerations of construction, and upon the power of rapid supply of steam to fill them. In the present case we have provided a capacity such that eleven trains may be passed before it becomes necessary to clear the condensor of air; it is therefore plain that if this operation were performed at every fifth train, the vessels might be of only one half the capacity here assigned. The generating power of the boilers being still the same, the rapidity of producing vacuum would be but little diminished. The question, however, of the most advantageous possible *size* of vessels under given conditions, is one requiring further investigation, based upon certain experiments which require to be made.

We are now enabled to determine the amount of vacuum that we shall obtain in the six miles of 15-inch tube by the use of the apparatus.

The capacity of the tube = 38872 cubic feet.

$$r = 38872 \text{ cubic feet.}$$

$$b = \frac{38872}{2} = 19436 \text{ cubic feet.}$$

Or assuming $r = 200$, and $b = 95$ as before, we have for the first stroke,

$$\frac{200}{95 + 200} d = 0.687 \times 30 = 20.34 \text{ inches of the rarefaction;}$$

and hence the vacuum at the first stroke,

$$30 - 20.34 = 9.66 \text{ inches of the vacuum-gauge.}$$

For the second stroke,

$$\frac{200^2}{(95 + 200)^2} d = 0.458 \times 30 = 13.74 \text{ inches;}$$

and hence the vacuum $= 30 - 13.74 = 16.26$ inches of the gauge.

And thus for the four first strokes we have the following results, without correction for vapour or evolved air:—

| | | | |
|---|---|---|---|
| 1st stroke . . . | 9.66 inches of vacuum-gauge. | | |
| 2nd „ . . . | 16.26 | „ | „ |
| 3rd „ . . . | 20.64 | „ | „ |
| 4th „ . . . | 23.61 | „ | „ |

Correcting for these we have the following nett amounts of vacuum, supposing no leakage by the long valve of the tube and tube piston, which we have next to consider, viz.:—

| | | | |
|---|---|---|---|
| 1st stroke . . . | 8.897 inches of vacuum-gauge. | | |
| 2nd „ . . . | 15.460 | „ | „ |
| 3rd „ . . . | 19.803 | „ | „ |
| 4th „ . . . | 22.736 | „ | „ |

To which we have further to apply a correction for the leakage taking place by the long valve, &c., during the time of exhaustion.

Supposing both vacuum vessels empty, and the steam surcharged in the boilers, and in a condition to blow off, which would be the state of the apparatus after the passage of one train, and at the moment when a vacuum was required for the second, in such a state of things three strokes can be completed in the time that the air will rush from the tube into the vacuum vessels, added to the time required to fill one vessel with steam, condense it, and again equilibrate its amount of vacuum with the air of the tube.

We need not go beyond the third stroke, because it is plain that at it we shall have a vacuum sufficient to start the train.

It is therefore necessary to determine the time of blowing off the steam into the vacuum vessels; of the air from the tube rushing into them, and of the condensation of the vacuum vessels full of steam, which latter is only limited by the time in which the steam from the vacuum vessels can get into the condensor.

These times cannot be correctly calculated for want of experimental data. The usual formula give no approach to the results shown by experience. Judging, however, from experience in analogous cases, I estimate that—

The steam at 45 lbs. will fill the vacuum vessel in from thirty to forty seconds, expelling the air before it; the dimensions of the tubes being such as shown on the drawings.

The air of the tube will equilibrate with the vacuum vessel in from twenty to forty seconds. The time of condensation will be ten seconds.

Now, Barlow states that the vacuum-gauge fell at Wormholt Scrubbs at about the average rate of four inches per minute, when all was at rest, by leakage, the vacuum being from twenty-one to twelve inches of mercury.

Now in vessels of unlike capacity, but with the same amounts of leakage and vacuum, the fall of the gauge in the same time will be inversely as the capacities of the vessels leaked into; and as in the present case the railway tube will be constantly in communication with *one* vacuum vessel of half its own capacity, the average fall of the gauge per minute, by leakage, on half a mile of 15-inch pipe, will be reduced in the proportion of the capacity of the 15-inch tube + the vacuum vessel, to the capacity of a 9-inch tube. We may, therefore, in round numbers, consider the leakage as equal to an average fall of the gauge of one inch of mercury per minute. The vessels, as stated, being already exhausted, the times of the first and second strokes will be forty seconds each, and the time of the third stroke will be about eighty seconds.

We have therefore at the first, second, and third strokes the following falls of the gauge due to leakage :—

| | |
|---|---|
| 1st stroke . . . | 0.66 inches of mercury. |
| 2nd „ . . . | 0.66 „ „ |
| 3rd „ . . . | 1.33 „ „ |

And deducting these from the previous amounts of vacuum in the tube, as stated, we have the following for the nett amounts of vacuum :—

| | |
|---|---|
| 1st stroke . . . | 8.237 inches of mercury. |
| 2nd „ . . . | 14.800 „ „ |
| 3rd „ . . . | 18.473 „ „ |

We have therefore at the third stroke a sufficient vacuum to start the train, and as good as that proposed to be obtained by the air-pump method. If the train start at this instant, we must continue to discharge the pipe as it advances of the air leaked into it, and remaining in it; and as the fall of the gauge may be taken at one inch per minute, it is obvious that four strokes made at equal intervals during

the transit of the train will more than meet this; or as the transit is made in twelve minutes, we must have one stroke made every three minutes, and for this the boilers are adequate.

We have thus then to complete the transit of one train over six miles of 15-inch pipe to make seven strokes. But we have already shown that each of these requires twelve cubic feet of water to be evaporated from 70° Fahrenheit into steam at 45 lbs. per square inch, and that each cubic foot so evaporated consumes 5.9 lbs. of coal. Hence, to pass one train over six miles, we must consume $5.9 \times 12 = 70.8 \times 7 = 495.6$ lbs. of coal; or say 500 lbs. of coal, including the power to feed the boiler and open valves.

We have further to determine the amount of power requisite for feeding the boilers with water, and for opening the valves, &c.

Four cubic feet of water is to be evaporated per minute at 45 lbs. per square inch = 3 atmospheres, which is equal to four cubic feet of water raised $3 \times 34$ feet = 102 feet + the lift of the suction pipe, say ten feet more = 112 feet in all. This is $4 \times 62.5 \times 112$ feet = 250 lbs. 112 feet per minute, or 28,000 lbs. one foot high per minute, or less than one horse power. The opening of the valves would probably, from their construction (double beat), not require one half of this —but assume it as much, then two horse power will be more than enough = 20 lbs. of coal per hour, or about 3 lbs. of coals per train passed over six miles.

Let us now compare this with the consumption of coal requisite to pass one train over six miles of 15-inch pipe by the present air-pump system.

At thirty miles per hour the six miles is passed over in twelve minutes. The air-pump must make as many strokes as will clear the pipe of air during this time.

At Wormholt Scrubbs, capacity of pump = 14.4 cubic feet, and the ratio of the pump to the pipe 1 : 85. Capacity of six miles of 15-inch pipe = $5280 \times 6 \times 1.23$ = 38966 cubic feet.

Ratio of tube to pump 38966 : 14.4, or as 2710 : 1. Hence the pump must make 2710 strokes in twelve minutes $= \frac{2710}{12}$ = say 226 strokes per minute.

The pressure for eighteen inches vacuum is 5.49 lbs. per square inch; 3.75 feet length of stroke $\times$ 226 = 846.5 feet per minute; area of pump = 1104 square inch.

Hence, $\frac{1104 \times 5.49 \times 846.5}{33.000} = 155.5$ horse power to discharge the pipe.

Assuming the piston and valve leakage the same nearly as for 9-inch pipe, and doubling *both* for the double length, (which will about compensate for errors

in additional joint leakage,) we have the total power for six miles of 15-inch pipe as follows, viz.:—

$$2(2.48 + 59.52) + 155.5 = 217.5 \text{ horse power, say } 217.$$

Increasing now the pump space in the ratio of 25 : 217, and the vacuum space as half a mile of 9-inch pipe to six miles of 15-inch pipe, or as 1166 : 38966, or as 1 : 24.8, we have—

The capacity of pump . . 125 cubic feet.
The capacity of vacuum space . 38966 „

or in the ratio of 312 : 1. The ratio of rarefaction is therefore $\frac{311}{312}$, and the number of strokes without leakage—

$$N = \frac{\log\ 30 - \log(30 - 18)}{\log 312 - \log\ \ 311} = \frac{1.477 - 1.079}{2.494 - 2.492} = \frac{0.398}{.002} = 199 \text{ strokes,}$$

to which adding fifty per cent. for lost power, makes $298\frac{1}{2}$, say 298, total number of strokes to obtain the vacuum.

Then as 58 : 298 :: 1′ 30″ : the time = 463″ = 7′ 7″.

Hence we have 217 horse power at work about eight minutes from starting to obtain the vacuum, and for twelve minutes to maintain the vacuum during the train's transit = in all twenty minutes, or one-third of an hour; and hence the amount of coal consumed to pass one train at 12 lbs. per hour per horse power, $\frac{12 \times 217}{3} = 868$ lbs., or at 10 lbs. per hour per horse power, $\frac{10 \times 217}{3} = 732$ lbs.; the former measure is that which may be in practice calculated on, reducing therefore the above in the ratio of 52,000 : 33,000 for nominal horse power, we have the nominal horse power = 138, and the consumption of coal at 12 lbs. per hour per horse power, required to pass one train, = 552 lbs.

It is therefore established that an economy of fuel or of power results by my method over the present system, in the ratio of 500 : 552, taking the least favourable views respecting my method, and assuming a perfection in the air-pump which does not exist.

The largest losses sustained in this method of exhaustion are those due to leakage by the long valve. And if Mr. Bergin's results as to its amount are correct, reducing it in the ratio of 3 : 8, the saving in power or fuel by this method would be greatly more considerable than I have here estimated it.

It has been shown that the rapidity of producing the exhaustion in the tube, or of obtaining the vacuum, is dependent with a given proportion between the capacity of the vacuum vessels, and that of the tube, solely upon the velocity with which air can rush into a vacuum through a long orifice.

I am warranted therefore in concluding that the practical limit set by construction and outlay to the size of the vacuum vessels, is within a very large range indeed, —the only limit set to the length of tube or distance between station and station. Six miles, therefore, seems by no means to be the utmost limit of this distance.

In comparing the rapidity of obtaining the vacuum in six miles of pipe by this method with that of the air-pump and 217 horse power, it will be observed that eighteen inches and upwards of vacuum is produced by this method in two minutes, whereas eighteen inches exactly is only obtained by the engine in seven minutes seven seconds. It seems therefore by no means vain to suppose that even three times this length, or *eighteen miles of pipe in one length, might be exhausted by this method.* The time of exit of the air at that length would not probably equal the time of exhausting six miles by the pump.

By combining this mode of producing the vacuum with my other proposal for storing or husbanding it, and also by the very nature of this apparatus itself, which, after the passage of a train, always will permit the steam of the boilers to be worked down in procuring and storing a vacuum equal to the capacity of both vacuum vessels, plus the condensor; and further, by the application of my proposed arrangements for withdrawing and smothering the fires of the boilers between the trains, I consider that nearly the whole power of the steam would be made available.

It is sufficiently obvious that this form of apparatus is at least as simple, and as little subject to derangement, as an engine and air-pump with boilers of equal power. I have therefore lastly to show how they stand comparatively as to outlay.

### ESTIMATE.

#### APPARATUS FOR DIRECT EXHAUSTION.

| | |
|---|---|
| 220 tons of boiler work | £5,575 |
| Jacketing | 600 |
| Engine and valve gear, &c. | 500 |
| Boiler setting connexions, foundations, and buildings over apparatus | 1,000 |
| Total | £7,675 |

#### APPARATUS ON EXISTING PLAN.

| | |
|---|---|
| 217 horse power engine and air-pump, at Samuda's estimate of £50 per H.P. for both | £10,850 |
| Saving on each station, or every six miles, in favour of direct exhaustion | £3,175 |

Without charging the existing system with any outlay for engine station buildings, the whole of which are included in the preceding estimate.

# DESCRIPTION OF THE PLATES.

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*Note.*—The same letters refer to the same parts of each figure in each plate.

## PLATE I.

### The Vacuum Vessels of Reports I. and II.

Fig. 1. Sectional ground plan of the vacuum vessels, and shed containing them.

Fig. 2. Transverse section of the shed, with end elevation of the vacuum vessels and their supports.

Fig. 3. Side elevation of a portion of one vacuum vessel, showing the peculiar system of support.

*a a a*, The vacuum vessels, cylinders with hemispherical ends, formed of boiler plate 5-16ths of an inch thick, riveted together, and properly strengthened by ribs inside.

*b b*, The short tubes of communication by which the three or more cylinders become one common vacuum vessel.

*c*, The man door for access to the interior of the vessels. This may otherwise be arranged as shown in Plate II. Fig. 2.

*d*, The pipe communicating with the air-pump by which the vessels are exhausted; this is provided with a double-seated valve, *r*, by which communication between the air-pump and vessels may be closed when the engine is stopped for oiling or any other cause.

*e*, The pipe connecting the vacuum vessels with the railway main-pipe, F, and also provided with a valve, *g*, which is maintained shut, except during the progress of a train along that section of the railway main-pipe to which the vacuum vessels belong. When the valve *g* is opened, the vacuum in the vessels is immediately shared with the railway main, before full of air, and with the results shown in the Reports I. and II. As the vacuum is thus *very suddenly* formed in the railway main, it is obvious that a much greater degree of staunchness will be conferred upon

the long valve by its being thus brought with an incipient blow on to its seat, than is possible by the existing plan of gradual exhaustion direct by the pump; and this applies to every modification of valve in which the atmospheric pressure on the main tends to render it *more* staunch, but does not apply to those constructed like M. Hallette's lip-valve, in which the tendency of the external pressure is to make the long valve leak in place of aiding to make it air-tight.

*h h*, Are thorough cross frames of whole timber, fitted with suitable chocks to receive the bottoms of the vacuum vessels, and upon which these rest. The position of these frames, with respect to the length of the vessels, is such that if any one vessel were cut in two at the middle of its length, each segment would just balance over the frame beneath it. These frames are connected by cross framing of cast-iron, the lower sides of which rest upon the roller carriages, *k k*, which again are supported by cast-iron rails, bedded upon stone blocks, upon proper masonry footings, *n n n*.

*m m*, Are diagonal struts of cast-iron, the lower ends of which abut against the masonry foundations, while their upper ends abut against the lower sides of the vacuum vessels at the centre points of their length. The object of this peculiar arrangement, as to support, is as follows: when the vacuum vessels are in progress of exhaustion by the pump, a very considerable reduction of temperature will take place within them, and, conversely, when the valve, G, is opened, and the air from the railway main is permitted to rush into them, a considerable rise of temperature will result within the vessels. Thus, from the effects of expansion and contraction, as well as from the changes of form and dimension due to varying external and internal pressure, these large vessels will be in constant motion on their supports; and if these were rigid, derangement would finally result, and the joints of all the pipes and attachments become leaky. To avoid this, the centre of the length of each vessel is made a fixture; and here the junction pipes and all other attachments are made, while from this point towards either end the vessels are freely at liberty to expand and contract, moving upon their roller supports with perfect ease and safety.

*o o*, Is the shell of the building to contain the vacuum vessels, which will be best preserved at as low a temperature as possible at all times.

*p p*, The roof over the building. Where the locality is favourable, the vessels may be advantageously placed in a vault beneath the line of railway, and they should be coated with a mixture of boiled coal-tar and caoutchouc to preserve them from rust, and also absolutely air-tight.

## PLATE II.

Fig. 1. Longitudinal section of a portion of one vacuum vessel, to a large scale, to show the method of construction.

*a a a*, The shell of the vessel, of plates of a thickness suitable to the diameter of the vessel; if this be 15 feet, plates of 5-16ths of an inch thick will be sufficient.

*ff*, Are annular deep ribs of stiffening plates riveted to the T iron, *g g*, with which the cross joints of the plates are formed. The longitudinal joints of the plates are flush outside, and double-riveted, with a strip or lap within, *e e e*, &c. The ribs, *ff*, also, are used at the ends, and converge to a ring at the axis of the vessel.

*b*, Is the main lid for access to the interior of the vessel, shown to a larger scale in Fig. 2. This lid is circular; a strong cast-iron coaming, *d d*, is riveted to the plates of the vessel, the rabbate in which is filled with bees'-wax and tallow; and into this rabbate the edge of the lid, *b*, drops, like a dish-cover, and being drawn down by the atmospheric pressure of the first exhaustion, remains quite air-tight, but can be lifted off at any time when the vessels are not exhausted, should such be required.

*c*, Is a weight to press down the lid at first into the luting in the rabbate; *n n* are the rings for lifting the lid off by.

## PLATE III.

### General View of the Apparatus for obtaining Vacuum by the Direct Condensation of Steam, referred to in Report No. III.

Fig. 1. Longitudinal section through A B of the station buildings, with side elevation of boilers, condenser, steam-engine, and valves, &c.

Fig. 2. Sectional ground plan of same.

Fig. 3. Transverse section through C D, with end elevations of the vacuum vessels, condenser, &c.

*a a*, &c., Are the six Cornish boilers, the construction of which is better shown in Plate V. Five are worked together.

*b b*, &c., The steam chests, on top of which are safety valves, as also duplicate safety valves at *c c*.

*d d*, The air tunnels, conveying draught to the fire-places, as shown in detail in Plate V.

*e*, The smoke tunnel, common to all the boilers, and conveying the smoke, &c., to the stalk, *f*, beneath the boilers. This tunnel is so arranged, that any one boiler can be worked irrespective of the others.

*g g*, The wheel work, or other gearing, by which the fire-grates are moved in or out from under the boilers when the latter are in or out of use, as shown in Plate V.

*h h*, &c., Stop valves, by which the communication of any one boiler with the steam pipes, *k k*, which are common to them all, may be cut off at pleasure.

*i i*, Man lids to the boilers.

*l l*, The feed pipe for supplying the boilers with water from the feed pumps wrought by the small engine, 5. This engine is worked by steam from the great boilers; its office is to feed the boilers and open the valves, *n o p*, by means of the cams; upon the cam shafts, 6, 6. 4 is the suction pipe of the feed pumps, which draws out of the hot well, 8, into which the condensed water from the condenser flows by the pipe 2; the overplus passing off by the drain, 3 3.

*m*, Is a long tube of boiler plate of large diameter, placed in the smoke place or tunnel, *e*, and which is always full of water; the feed pump discharging into it at one end, and the feed delivering into the boilers at the other, so that the feed water passes into them nearly boiling.

*n*, *o*, and *p*, Are double-seated valves, moveable either by hand from the engine room below, or by the cams wrought by the engine, at pleasure. The offices of these valves are as follow: when *n* and *o* are both open and *p* shut, steam is free to enter the condenser, T, from the boilers; *n* being closed and *o* continuing open, with the jets of water playing into the condenser, a vacuum more or less perfect is formed in either the right-hand vacuum vessel, V′ V′, or in the left-hand one, V V; *n* and *o* being both closed, and *p* opened, the vacuum vessels are placed in alternate communication with the railway main, *s*, by means of the pipes *r r*, and share their vacuum therewith.

*w w*, The water main and stop valve by which the jets of condensing water are admitted or cut off from the condenser, T, during the whole time of one set of exhaustions of the vacuum vessels. These jets of water are kept constantly playing into the condenser. The condensing and condensed water are withdrawn from the condenser by means of the large syphon tube, 2 2, whose total height from the surface of the water in the hot well, 8, to the bottom of the condenser is at least 34 feet. The water, therefore, continues freely to flow off from the extremity into the drain, 3 3, but no air can enter the condenser by the same pipe.

*x x*, Are similar syphon pipes, but of a much smaller size, to relieve the vacuum

vessels of the small quantity of condensed steam which will be produced in them by the contact of the steam blown into them, with the wood lining of their sides.

All the vacuum vessels, as well as the condenser, are lined with wood and jacketed outside, in the way particularly shown in Plate IV., so as to reduce the condensation by contact of the vessels as much as possible, inasmuch as in the case of the vacuum vessels all cooling, and in that of the condenser all heating, will be attended with waste of steam.

*y′ y′*, *y y*, Are the snifting valves of the two sets of vacuum vessels.

*z z*, The much smaller snifting valve of the condensor.

It appears to be immaterial at what level of the vacuum vessels the steam is blown in, provided it be blown *very* rapidly in, so as not only to *displace* the air and discharge it at the snifting valves, but to expand it and cause it to pass out by its increased bulk. From the very small difference in specific gravity that exists between steam at 212° and common air at 50° or 60° Fahr., and from the tendency to mutual diffusion, it is quite a mistake to suppose that in vessels of great capacity any distinct plane of separation can be preserved between steam and air. In comparatively small vessels a separation may be observed; but in large vessels, if the steam be blown in slowly enough to preserve such, mutual diffusion takes place; if rapidly, mixture; but if *very rapidly*, the air is driven out before the steam. This being the true principle of "blowing through," it is not important where the steam is admitted, provided the vacuum vessels are of a long tubular form, and that the passages for the egress of the air be at the ends remote from the steam entrance. I do not, however, confine myself to a horizontal position for the vacuum vessels, nor to any particular place for admitting steam. At first it occurred to me to have two very light disks or diaphragms, which without touching the sides of the vacuum vessels should, on the admission of steam, be driven before it, and parting from the centre aperture at *o*, right and left, pass to the two opposite ends of the vacuum vessels, driving the air out before them, and, on arriving there, be slowly brought back by a balance weight within the vessel; but this, after some consideration and experiment, seemed needless. Perhaps, ultimately, the best form of vacuum vessel, in every respect, would be a sphere; the steam to be blown directly in at the top, and the air blown out, by snifting valves arranged round the horizontal diameter and at the bottom. This would also give the greatest economy of material and space in their construction.

The water is assumed in the Plate III. to be supplied to the condenser by the pipe, *w*, from an elevated head or source.

The mode of action of the apparatus has been fully explained in the Report No. III.

77. Is the shell of the station building, containing the exhausting apparatus.

99. The roof over same. These of course may be varied to any extent.

## PLATE IV.

### Details of Construction of the Condensor.

Fig. 1. Longitudinal section of part of the condensor, at one extremity.

Fig. 2. Partial transverse section of same.

*a a*, The interior of the condensor.

*b b*, The shell of the vessel, formed of boiler plate stiffened by *external* ribs riveted to angle iron, *f f*.

*c c*, The wood non-conducting lining, formed of staves of yellow pine fitted in longitudinally, and of curved pieces fitted to the concave ends of the vessel.

*d d*, The external fir sheeting forming the outside of the jacketing. This surface of 1 inch fir surrounds the whole vessel at a distance of some inches, and is secured to the external ribs by square slips of wood screwed through these. The interspace between the sheeting and the plating of the vessel is filled in with dry sifted ashes mixed with sawdust, *e e*.

*g*, One of the blocks of stone upon which the condensor rests, being immediately sustained by the concave chocks, *n*, fitted to the lower side of it. As the inner lining is intended to prevent any sudden or considerable changes of temperature in the vessel, and as it is also jacketed outside, there is no necessity in this case for providing against expansion and contraction in the structure of the supports, as in Plate I.

*k*, The communication pipe with one of the vacuum vessels, *v′ v′*, or *v v*.

*l*, The main supplying the water for condensation, capable of regulation or of being shut off by the valve, *m*.

*n*, Is the pipe of distribution, pierced full of holes along the upper part of its surface, and running the whole length of the condensor; so that jets of water play up into the body of the condensor at all points.

*o*, The snifting valve, the upper side of which is kept immersed to a small depth in water, so that the progress of blowing through may be told by the cracking noise usually known to be produced by the passage of steam through cold water. The water is fed into the snifting valve troughs by a small pipe.

The construction of each cylinder of the vacuum vessels is precisely similar to that of the condensor, with the exception of the supply of water. The lining and

jacketing are the same. The snifting valves are larger, but immersed in water, and balanced in the same way, so as to be capable of being opened by the feeblest possible pressure from within.

## PLATE V.

### Longitudinal Section of a portion of one of the Steam Boilers, showing the details of Construction of the Fire Apparatus, etc.

*a a*, The cavity of the boiler, steam and water spaces. The boiler is of the Cornish form, i. e., one cylinder excentrically within another; the fire being in the inner one, which, beyond the bridge, forms the first flue, and in the centre of which, and therefore surrounded with flame, is placed the tube, *á*, wholly filled with water. The flame and gases, &c., of the fire pass off over the bridge, from the fire-places at *both ends* of the large boilers here designed. Towards the centre of the length of the boiler, a brick wall of separation is built across the internal flue, at either side of which the draught from the fire at one end or the other, passes down through an aperture in the bottom of the internal flue, or through the water space; thence it returns under the bottom of the boiler, towards the two ends, from *v* to *w*, and at *w* the flue splits, and one-half the draught passes at either side of the boiler back again to the centre, and so into the tunnel or horizontal flue, (*e*, Plate III.,) and into the stalk. This arrangement gives an immense fire and flue surface, with that sort of draught that answers best in Cornish boilers, and economizes fuel so completely.

*b b*, Is the fire-grate (the same at each end of each boiler). The grate rests upon a complete frame of cast-iron, carrying with it the fire-door, *i*, and lined all round inside, or next the fuel, with fire-brick. This frame is made to traverse on the rollers, *c c c*, either from *c* to *p*, or *vice versâ*, by means of the wheels and pinion, *r d*, in dotted lines, outside the setting, and connected with the toothed pinion and roller, *c′*, taking into a rack attached to the frame, 6 6.

*f*, Is the ash-pit under the grate, formed to be cleared by the rake, *g*, which draws the ashes down into the ash-tunnel, *n*, whence they are removed without interfering with the draught.

*m*, Is the cold air tunnel to supply draught to the fire, through the grated ventilator, *n n*, which is made to open or close by the lever and balance weight, *p o*. *y z*, the directing plate for the entering current of air.

*e*, Is the bridge, *t t* the internal flue, *v* the lower flue under boiler bottom, *w* the entrance therefrom to the side flues.

The boiler is at work in the position of the fire-grate, &c., shown in the figure, and the air to supply it passes up through the ventilator, *n n*, and taking the general

directions shown by the arrows, passes under the grate, 6 6, and through the fire, &c.

When the boiler is not required to generate further steam for a time, the fire and fire-grate are withdrawn or moved back from under it by the wheels, *r d*, &c., and run back under the fire-brick arch, A, until the internal fire door, *i*, comes in contact with the frame of the outer one, *k*. Fresh fuel is now thrown on, and all the doors, *i k*, and the outer air-doors, *l*, closed home.

In the act of running back the fire-grate, 6 6, the stop, *q*, strikes the lever, *p p*, and shuts off the supply of air to the fire through *n n*. The fire can now no longer burn freely, but the heat radiated from its upper surface, in place of being expended in generating steam immediately in the boiler, is now absorbed by the brickwork of the arch, A, which becomes red hot.

If things were preserved long enough in this state, the fire would go wholly out, but as these boilers are required at intervals of from half an hour to an hour or so this does not occur. Steam is now again required; for this purpose the fire-grate is again run forward under the boiler, as shown in the plate; in doing so the air is re-admitted through *n n*; and by the directing plate, *y z*, the currents are caused to sweep under the surface of the heated arch, A, and side-walls of the chamber, *d k*, the whole of the heat of which is thus carried away and swept through the flues of the boiler. Thus, by this arrangement, the heat of the fire that would be otherwise lost between the times of trains is husbanded by being absorbed by the brickwork as in a magazine, and is at once when wanted given back and made use of. It is obvious that this construction of boiler is applicable to every operation requiring the intermittent use of large volumes of steam, as well as to the existent mode of exhaustion upon atmospheric railways. The fire-place should be so proportioned that the fuel shall need no poking or raking, and no supply except at the intervals when drawn back under the arch, A, when the bars may be cleaned; a large deep body of fuel, slowly but perfectly burnt by a sufficient supply of air, will be found always to give a more economical result than what is called "thin firing" with continual stoking.

The tops of the boilers are covered to the depth of some inches with sifted ashes, *s s*, as jacketing.

## PLATE VI.

### DIRECT ACTING CONDENSATION VACUUM VESSELS.

The exhaustion proposed being effected by this arrangement, consists in the combination of the method of displacement of air from the vacuum vessels, by filling them with water, with that of direct condensation of steam; the same water being

used for both purposes, and leaving the vacuum vessels entirely empty, after having passed into the condensors which are placed at a lower level.

Fig. 1. Is a plan of the steam boilers, condensors, and vacuum vessels, with station, shed, and part of the atmospheric main.

Fig. 2. A longitudinal section of same.

Figs. 3, 4, 5, and 6, are diagrams to render the operation of this arrangement when in use more intelligible.

The same letters refer to Figs. 1 and 2.

*aaa*, The vacuum vessels of boiler plate.

*b*, The water-main and valve by which the vessels may be completely filled with water from an elevated source or natural head; the displaced air being expelled by snifting valves, placed on top of the connecting main-pipe.

*c*, The pipe of communication with the atmospheric main, furnished with a double-seated cut off valve.

*e*, The pipe of communication between the vacuum vessels and the condensors, with cut off valve.

*eee*, The condensors also of boiler plate, but lined with wood to prevent waste of steam.

*h*, The waste valve and pipe by which the condensors may be emptied of water into the sewer, *k*.

*ff*, The steam boilers, upon the locomotive plan; the draft being downwards into the flue, *l*, and away to the stalk, *m*.

*gg*, The steam-pipe and valves.

*o*, The roof. *nn*, the shell of the station building.

*p*, The atmospheric main and railway.

OPERATION.

The vacuum vessels are first filled with water, expelling thereby the air. At the same time, the condensors are filled with steam from the boilers, the valves *c* and *d* being shut. This is the first operation, as shown in diagram, Fig. 1.

The valve *b* of the water main, and the supply of steam from the boilers are both now shut off, and the valve *d* is opened, forming communication between the vacuum vessels and condensors. The water condensing the steam rushes into the latter, and when one-half the volume of water has descended, leaving its whole quantity equally divided between the vacuum vessels and condensors—the communication valve *d* is shut. There is then nearly half a vacuum, say 14 inches gauge, in half the capacity

of both vacuum vessels and condensors. This is the second operation or period, shown in Fig. 2.

As soon as the valve *d* is shut, the waste valve *h* is opened, and steam again thrown into the condensors from the boiler. The water having escaped (and where the levels will suit it, may be drawn off by a vertical pipe of more than thirty-four feet in length, with advantage), the condensors are again filled with steam. This is the state of the apparatus shown in Fig. 5.

The steam is now shut off from the boiler, the waste valve also closed, and the valve *d* between the vacuum vessels and condensors opened. The water remaining in the former now descends into the condensors—condensing the steam therein—and leaving a nearly perfect vacuum in the vacuum vessels, and in one-half the capacity of the condensors. This is the last operation shown in Fig. 6.

Thus, by the expenditure of rather more than two condensors full of steam, and one vacuum vessel full of water, we obtain a nearly perfect vacuum, say twenty-eight inches gauge in the vacuum vessels, and half the condensors.

In other words, if the vacuum vessels and condensors be of equal capacity, we obtain a volume of nearly perfect vacuum space $=1.5$, from the expenditure of a volume of steam $=2$, and of water $=1$.

This was one of the earliest methods that occurred to me for procuring vacuum by the direct action of steam and water.

## PLATE VII.

Design as originally made for Water Vacuum Vessels, or Apparatus for obtaining vacuum for Atmospheric Railways, by the emptying of vessels of water by tubes of more than thirty-four feet in height. On the "Torricellian Principle."

Fig. 1 is a plan, Fig. 2 a longitudinal section of the apparatus, with cross section of part of an atmospheric line of railway upon an embankment, which gives the requisite difference of level for the descent of the water by the syphon pipes.

*aaaa*, The vacuum vessels. *b*, The water-main supplying them from a natural head. *c*, The stop-valve on the main.

*ddd*, The vertical syphon pipes for emptying the vessels. *eee*, The stop-valves at upper end of same.

*f*, The delivering shoots by which the waste water is thrown out, on the level of the surface *g*.

*hh*, The pipe communicating from the vacuum vessels to the railway main and furnished with a cut-off valve, *k*.

*l*, The railway main. *mm*, The shell of the station building. *n*, The roof. *o*, Slope of the embankment.

OPERATION.

The vacuum vessels being completely filled with water by the main *b*, the valve *c* is shut; the valve *k* being also shut. The valves, *ee*, are opened, and the vessels empty themselves by gravity, and are left nearly in a state of perfect vacuum. The valves, *ee*, are shut, and the valve, *k*, of communication with the railway is opened, whenever it is requisite that the vacuum vessels should exhaust it for the passage of a train.

This arrangement was devised by me early in 1843.

## PLATE VIII.

THE DETAILS OF A NEW LONG VALVE AND MAIN FOR ATMOSPHERIC RAILWAYS.

The objects in view are to reduce the cost of the main and valve, simplify their parts, and diminish leakage, which occurs to so great an extent with Clegg's valve. The main is cast with a pair of jaws, one at either side of the long slot through which the coulter travels. These jaws are formed to a particular curve, (see Plate IX.,) and are cast against "a chill," by which they are obtained perfectly smooth, fair, straight, and hard, and thus the cost of "planing" the valve faces is avoided. The valve consists of a continuous hollow tube or hose of woven hemp, coated throughout with caoutchouc, like the tube of a stomach pump or other such instrument. This tube is maintained full of water, (or brine in cold climates,) and when it is closed as a valve, is forced in between the jaws of the main, and acts like a sort of continuous cork. As the coulter, &c., travels along, the tube is lifted up a few inches out from the jaws, by suitably formed rollers; and as soon as the coulter has passed, it is pressed back again into the cavity between the jaws, by a roller pressing upon its upper surface.

In place of a hollow hose full of fluid, under a constant small head, or of compressed air, a compound continuous cork, formed of four cotton ropes, embedded in caoutchouc, and having the peculiar external form required, may be used, as shown in section to half size (Fig. 2, Plate IX.). This is, in fact, one of Brockedon's patent stoppers of indefinite length—either arrangement would admit of sufficient extensibility in length to allow the lifting up and pressing down of the valve at the passage of the coulter without injury.

The outer surface of the valve, in either case, should be coated with an unguent

which will not act on the caoutchouc; if vulcanized india rubber be used, common palm oil will answer.

Pinkus's valve was a continuous flat band of leather, and failed, because when close it had no tendency to keep in contact with its seat, and its edges were *thrown up* by the pressure of the atmosphere on its centre part.

Hallette's valve consists of *two* continuous tubes full of compressed air, by the elasticity of which they are forced against each other, and the main thus attempted to be made staunch—but the serious defect appears to be, that the tendency of the atmospheric pressure upon the outside of these artificial lips, is to force them asunder, so that the exhaustion of the tube tends to produce, in place of to diminish, the leakage of the valve. The present contrivance, which has something in common with both Pinkus's and Hallette's arrangements, though invented long before the latter published his plan, appears free from the disadvantages of either, and to possess several advantages not offered by any other valve proposed.

The letters refer in common to all the figures Fig. 1, Is a plan and section horizontally of the atmospheric main, *aa*.

*bb*, The valve seat or jaws, cast with "chilled" faces. (These are best seen in section in Plate IX. Fig. 1.) The lengths of main are put together with abutting rabbated flanged, or rather lugged joints at every fifteen feet, with a flange of India rubber three-sixteenths of an inch thick between—the elasticity of which allows for expansion of the main, and yet keeps the joints air-tight.

From the facility given for support of "the cone" by the "chill" in casting the valve-seat faces—the main, as thus designed, can be as readily cast in 15 feet as in 9 feet lengths, which has been the limit of Samuda's practice. *c*, Is the tubular valve of woven hose, covered with caoutchouc, or of caoutchouc and cotton solid; it is here shown hollow, and is maintained full of water by a small flexible tube, *d*, at either end of the section of main, joined to its extremity by the brass nozzle and bend, *e*. This little tube connects also with a small water main, *f*, laid under the ballast of the road, and in connection with a head of from 5 to 10 feet of water, by which the tubular valve is always kept full and "plump." This little supply tube is so placed as to be passed by the coulter, &c., and to permit the valve to be lifted up and pressed back again into its seat.

*g*, Is the travelling piston head. *h*, The rib or frame of the travelling gear. *k*, The balance weight. *lmno*, The hollow grooved rollers, made like ordinary "sheaves," which gradually *lift* the tubular valve out of its jaw-shaped seat, to permit the coulter to pass with the piston. The first and last of these, *l* and *o*, are narrow enough to pass up between the jaws or into the longitudinal slot—and are of

hardened steel. *r*, Is the roller with a slightly concave edge or rim, which attached to the perch of the leading carriage, *s*, presses down the tubular valve into its seat, something like forcing a continuous cork into the neck of a bottle, and so leaves the main ready for fresh exhaustion after the passage of a train. *t*, Is the coulter of plate iron, five-eighths of an inch thick, carrying the rollers, piston, &c., &c., and attached to the perch, *s*.

## PLATE IX.

### Enlarged transverse section of the improved Main and Valve.

Fig. 1. *aa*, Section of the main to scale of 6 inches to the foot. *bb*, The valve seat, the opposite faces chilled. *c*, The tubular valve in its seat—when raised at the passage of the coulter it assumes its cylindrical form, as shown in dotted lines. *dddd*, passing over the sheaves or rollers, *m*, &c. *t*, Is the coulter seen endwise. *h*, The rib of the travelling piston.

Fig. 2, Section to 6 in. scale of the compound continuous solid valve, consisting of four cotton or Manilla soft ropes, *ss*, embedded in a coating of caoutchouc, *r*, externally formed to the proper shape, viz., such as the tubular valve assumes when in its seat.

## PLATE X.

### Details of Arrangement for releasing the Head of the Travelling Piston instantaneously in case of accident on the Line or to the Train.

Professor Barlow, in his Report to the Board of Trade, remarks upon the inefficiency of Clegg's contrivance for suddenly bringing an atmospheric train to rest in case of accident, namely, by opening a valve in the back of the piston; and justly concludes that "the atmospheric system will be inferior in point of safety to rope machinery, without some contrivance for totally and immediately disconnecting the piston from the train." The piston, *with its coulter*, &c., could not possibly be let go from the leading carriage, without the destruction of more or less of the long valve, however formed, by its first plunge forward—but the piston head may be released from all the rest, and let to shoot forward within the tube without injury either to itself or the main or valve. This arrangement for doing so I devised in 1842.

*Figs*. 1 and 2 are a horizontal and vertical longitudinal section of the main, with piston, coulter, &c., fitted for my own improved valve—and with gear for releasing the piston head.

Fig. 3, Is an enlarged plan of the clutch for retaining or releasing the piston head, and Fig. 4 a transverse section of same, through A B. The same letters refer to all. *a*, The main. *q*, The piston head. *h*, The rib or frame of the piston. *k*, The balance weight. *lmnop*, The lifting rollers of tubular valve. *t*, The coulter. *s*, The perch of leading carriage. The piston frame at *r* consists of a cylindrical socket, into which a solid cylindrical bar, or plug, fast to the piston head, fits, as shown in dotted lines, Fig. 3. At either side of *r* are provided wings, forming rabbates, into which the two clutches, *v v*, are placed, and are free to move back and forwards on the centre pins, *w w*. The hooked ends of the clutches, when in the position of Fig. 3, are engaged with the plug, *x*, of the piston head, by slots or cotter holes at either side of it, which they enter. The collar, *y*, slides along over the clutches, and when moved towards *r*, holds them in their place, and keeps the piston head securely attached. When the piston head, however, is required to be suddenly detached, the sliding collar, *y*, is pulled back towards *q*, and as it passes over the projecting ends of the clutches, *vv*, which are inclined outwards, it pulls them out of hold with the bar, *x*, of the piston head, and the latter being released, flies away, leaving the piston frame, &c., behind.

The motion of the collar, *y*, is produced by the rods, *z z*, attached to it, and to the levers, *c c*, moved at the other end by the rods, *dd*, which unite into a single rod, passing vertically up through the valve slot, cranked to one side to let the tubular valve pass, and finally moved by a hand-wheel, whose centre is a fixed nut, taking into a rapid screw on the rod *d*. This wheel is at the immediate command of the conductor.

# APPENDIX.

The five following letters or documents substantiate the date at which my inventions were made and communicated. The extract from the minutes of the Royal Irish Academy only goes back to the period in 1843, when having reason to think I might not be able hereafter to prove date by the aid of those to whom my communications were first made, I lodged a sealed packet containing copies of my three Reports with the Academy, which was since opened and read.

No. 1.

London Coffee House,
2nd June, 1845.

My dear Sir,

Your letter of the 29th ultimo has only this day reached me.

I cannot tell you the *precise* date at which you laid your plans before me, for husbanding the vacuum for use upon Atmospheric Railways, by the constant exhaustion of reservoir vacuum vessels, but I have no doubt from what you state that it was in November, 1842.

You probably have a letter of mine which will fix the date within a period quite sufficient for your purpose, in which I shall be most happy to afford you, on my return home (or here), any assistance in my power.

Yours very truly,
JAMES PIM, Jun.

Robt. Mallet, Esq.

No. 2.

Dublin and Kingstown Railway,
1st June, 1845.

Dear Sir,

The reference in your letter of yesterday to the allusion made by me in the "Observations" to your proposed methods of exhaustion for Atmospheric Railway purposes, has afforded a clue, by following which I am now enabled unhesitatingly to say, that you had communicated them to me before the 1st of November, 1842; and as you seem to attach some importance to date on this subject, I will state those which enable me to speak so confidently.

In the first place, the allusion in the "Observations," at p. 60, to other modes of exhaustion, and to competent individuals being engaged in experiments and investigations on the subject, solely refers to your plans. Secondly, I was in London about the 1st of November, 1842, till about the 10th or 11th.

I therefore feel perfect confidence in repeating, that prior to the 1st of November, 1842, I had been informed by you of your two modes of producing exhaustion in an atmospheric main, viz., by the direct action of steam in expelling the air from close chambers and then condensing the steam; and by keeping air-pumps constantly working in exhausting the air from large reservoirs, with which, from time to time, as required for propelling of trains, communication was to be opened from the main.

Whether your detailed drawings and computations had been completed at the time, I cannot say; I mean, whether before the 1st of November, or no. But this I am certain of, that if they were not completed before that day, they were finished and shown to me very soon after my return from London, and *previous* to another journey there at the end of December, 1842.

I am, dear Sir,

Yours faithfully,

F. F. BERGIN.

R. MALLET, ESQ.

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No. 3.

ay 31st, Observatory, Armagh.

MY DEAR SIR,

I have no opportunity of seeing the Comptes Rendú, except when in Dublin, and therefore am not acquainted with the communication of M. Arnollet; but I distinctly recollect your plan, and my making some investigations respecting it, in the end of 1842. I called it "storing-up vacuum," and besides the other advantages which it appeared to me to possess, I attached peculiar importance to its power of economizing the steam power, by working the engine continuously during the intervals of trains, and the facility of obtaining a higher velocity in consequence of the train being less likely to overrun the air-pump; the magnitude which I assumed for the vacuum vessel was five times the capacity of the main. I cannot find my papers, but I think it most likely that I gave them to Mr. Bergin, or Mr. Pim. If this attestation of the time at which your plan was communicated to me appear of any use you are welcome to use it.

Believe me,

Yours ever,

T. R. ROBINSON.

R. MALLET, ESQ.

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No. 4.

32, L$^r$. Baggot Street,
May 31st, 1845.

MY DEAR MALLET,

In the winter of 1842 you communicated to me certain projects of yours, having for their object the improvement of the Atmospheric method of propelling trains on railroads, invented by the Messrs. Clegg and Samuda. As well as I recollect, you proposed to yourself to accomplish the two following distinct objects:—1st. To substitute for the large engine at present used for pumping out the air, one of much inferior power, which should be constantly in action and be applied

in exhausting a large reservoir, to be connected with the main tube of the railroad by a pipe furnished with a valve, by means of which the vacuum produced in the reservoir might be rapidly shared with the railway tube traversed by the piston.

2nd. Eventually to dispense altogether with the stationary engine, with the exception of its boiler, and to produce the vacuum according to the well-known method of *blowing* out the air, and then condensing the steam by which it was expelled.

I have a very distinct recollection of your having consulted me on some points connected with these schemes, and your having told me that you were negociating with certain parties interested in the Atmospheric principle, with the view of securing your inventions by patent. I may add, that the first of your proposals appeared to me to be one of great promise, and I am still of opinion that it cannot fail of being sooner or later adopted, should the Atmospheric system stand the test of experience, and come into more general use.

Always and very truly yours,
JAMES APJOHN.

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## No. 5.

Extract from the Minutes of the Meeting of Royal Irish Academy, held 26th May, 1845.

"Mr. J. Huband Smith (Sec. pro tem.) read to the Academy the minutes of the proceedings of the 13th November, 1843, a statement of the deposit of a sealed packet with the Academy, on that day."

Extract from Minutes of Royal Irish Academy, of 13th November, 1843.

"A sealed packet was deposited with the Academy, by Mr. Mallet.

"The packet above-mentioned was ordered by the Academy to be opened, with the consent of the Author, which being done, Mr. Robert Mallet stated briefly the subject matter of the enclosed documents, and his object for calling for the production of the packet upon this evening.

"The packet contained three MSS., descriptive of Mr. Mallet's improvements in obtaining vacuum power on Atmospheric Railways, and they were now opened in order to make reclamation of priority of invention as against Mons. Arnollet, a French Engineer, and Mr. Nasmyth, of Patricroft, near Manchester; and the MSS. were again sealed by the President, and also by Mr. Huband Smith, acting as Secretary pro tem., in the presence of the Academy."

(A correct copy.)
"EDWD. CLIBBORN,
"Clerk Royal Irish Academy.

"26th May, 1845."

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My communications as to the constant exhaustion of reservoirs and exhaustion by direct condensation of steam, were made under pledge of secrecy to Mr. James Pim, junr., to Mr. Bergin, and to Mr. Kirkman; and were under a similar condition communicated by Mr. Pim, with my permission, to the late Mr. Jacob Samuda.

The following Note explains the origin of my second Report.

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No. 6.

Wednesday, 7 Dec. 1842.

MY DEAR SIR,

I think it would be well for you to get out a second set of moving, &c., results on my data, if there be time. I send a proof of my paper [a], in which you have all the tables. The text I have not corrected, as you do not want it.

Yours,

T. F. BERGIN.

R. MALLET, ESQ.

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It has been previously stated, that on my communicating my inventions to the above parties, they were viewed by them as having been fully substantiated, and as being perfectly original; and the immediate result was a negociation for the purpose of taking out a joint patent. This is indicated by the documents, Nos. 7 and 8.

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No. 7.

(Copy.)

WESTLAND ROW,
Tuesday, 2 P.M.
(No date. Received 6th Dec. 1842.)

MY DEAR ROBT.

Samuda and my brother Greenwood, and no one else, dine with me to-day.

If you are quite disengaged, and are inclined to talk over *all* or *any* of your inventions, I will be glad to have the pleasure and advantage of your company. Bergin has informed you that Dr. Robinson will not be with us to-morrow. I hope we shall have that pleasure on Friday, and beg that you will keep yourself disengaged.

Yours ever,

JAMES PIM, JUN.

ROBT. MALLET, ESQ.

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No. 8.

DUBLIN AND KINGSTOWN RAILWAY,
48, Westland Row,
7th January, 1843.

MY DEAR SIR,

For the last fortnight I have had such a pressure of official matters that I was unable to go into your scheme. I have now read your paper on the reservoir plan, and although your results are contrary to what I expected, and I have not seen why, still I cannot find any flaw in your arguments or the principles of your calculations, considering them only approximative. I may add

[a] *i. e.* The Observations on Barlow's Report.

that the exact investigation of one of your cases, by Dr. Robinson, leads to results so similar to those you have obtained, as to satisfy me that your method, provided it can be mechanically worked out, does effect a material saving of power over and above the production leakage power, all of which is saved. By mechanically worked out, I mean, that if the expenditure of power by the steam engine can be made constantly equal to the constantly varying resistance of the air-pump. That much may be done in this respect, I am aware, but it is for you to say how much: and your economy over and above leakage saving will be more or less as this is more or less effectually accomplished.

Believe me,
Yours faithfully,
T. F. BERGIN.

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Some days, however, after communication had been made to Jacob Samuda, I was informed by Mr. James Pim, that he (Samuda) affirmed that my reservoir plan was altogether anticipated by Clegg's patent, in the specification of which it appeared, that he believed, notwithstanding, that the method was perfectly useless, and would be attended with a loss in place of any economy in power; and in proof of this, I was handed a calculation by Samuda, the value of which may speak for itself.

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No. 9.

(Copy, verbatim, of the late Jacob Samuda's memorandum, dated 9th Dec. 1842.)

16) 52.24 (3.26 lbs. mean per □ in. from 0 to 16 in. vacuum.
42
104
8

8) 42.65
5.33 lbs. mean per □ in. from 16 in. to 24 in. vacuum.

A pump containing 30 *c F* will extract a mean of 22 *c F* of solid air per stroke, while exhausting reservoir from atmospheric density to 16 in. mercury; if, therefore, the reservoir contains 100 *c F*, it will acquire a rarefaction 16 in. mercury in 2.42 mins.

3.0) 16

22) 533 (2.42 The same pump will extract a mean of 10 *c F* of solid air, per stroke, when exhausting a reservoir from 16 in. to 24 in. mercury,
93
53

3.0) 80.0 therefore it will effect this increase in the same reservoir, in 2.66 mins.
26.6

The power exerted in the former case will be 3.26 lbs. × 2.42 mins. =
and in the latter case, 5.33 lbs. × 2.66 mins. =

but as the reservoir would be but half the capacity in the first case, the reservoir being necessarily twice the contents of the main, the former result must be divided by 2.

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Mr. Pim added, that his own views as to the value of the invention were unaltered, and that if on reference to the specification it were found that a patent could be taken by any one, and the Messrs. Samuda should not be willing to join in one, he would undertake this:—"That no opposition should be given to my taking one myself; that in this respect I should be left in the same position as before our negotiation began."

How far this undertaking was ratified after the lapse of several months, a subsequent document will show.

After some delay, I got a copy of Clegg's specification, and it was proposed by the atmospheric patentees, to submit *a joint case* to counsel, for the alleged purpose of determining if any thing expressed in Clegg's specification precluded a patent being now taken for my inventions.

This joint case (though measures were taken to prepare it) was never submitted, but, without any previous knowledge or accordance of mine, *an ex parte case* was submitted to counsel, as given below, together with a copy of Clegg's specification, in which the passage assumed to be in anticipation of my inventions is printed in italics.

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No. 10.

To all to whom it may concern, be it known that we, Samuel Clegg, of Sidmouth Street, Gray's Inn Lane, in the county of Middlesex, and Jacob Samuda, of Southwark, in the county of Surry, Civil Engineer, have invented or discovered a new improvement in valves, and the combination of them with machinery; and we, the said Samuel Clegg and Jacob Samuda, do hereby declare that the nature of our said invention and the manner in which the same is to be performed are described and ascertained by the drawings hitherto annexed and the words following, (that is to say,) our improvement consists in a method of constructing and working valves in combination with machinery. These valves work on a hinge of leather or other flexible material which is practically air-tight (similar to the valves commonly used in air pumps); the extremity or edge of these valves is caused to fall into the trough containing a composition of bees'-wax and tallow, or any other substance or composition of substances which is solid at the temperature of the atmosphere, and becomes fluid when heated a few degrees above it. After the valve is closed, and its extremity is lying in the trough, the tallow is heated sufficiently to seal up or cement together the fracture round the edge or edges of the valve which the previous opening of it had caused, and then, the heat being removed, the tallow again becomes hard and forms an air-tight joint or cement between the extremity of the valve and the trough. When it is requisite to open the valve, it is done by lifting it out of the tallow, with or without the application of heat, and the before-named process of sealing it or rendering it air-tight is repeated every time it is closed. This combination of valves with machinery is made in the application of these valves to railways or other purposes by a line of partially exhausted pipes, for the purpose of obtaining a direct tractive force to move weights either on the railway or otherwise. This we effect by laying down a continuous length of pipe containing a lateral slit or opening its whole length; a piston is made to travel in this pipe by exhausting or drawing out the air from the pipe on one side of the piston, and allowing free access to the atmosphere on the other side of it; an arm from this piston passes through the lateral opening

to attach to the carriages on the railway, and draws them along with it. The whole of this lateral opening is covered by the valve before described, and that part of it through which the arm passes is lifted to allow it to pass, and also for the admission of air to the piston, by means of an apparatus connected to the arm. The carriage to which this arm is attached we call the driving carriage. To the hinder part of this carriage a long heater is attached, which is drawn along by it upon the tallow contained in the trough, and reseals the valve ready for the next train, which repeats the operations above described at certain distances, which are regulated by the nature of the road. Steam-engines and air-pumps or other apparatus are fixed for exhausting the pipes, (these engines we propose to place about one mile apart in the first instance, and to vary the distance either for greater or less, as we find to be most economical in practice,) and at a short distance beyond the connexion from the engine to the pipe valves are placed, closing the end of one length or section of pipe and the beginning of the next, between which a space is left for stopping the trains if required. These valves also divide the pipe into suitable lengths to be exhausted by each apparatus, or close the end, where it is not required to be continued, as on declivities where the carriages will run by their own gravity. Thus every section of pipe is inclosed at the two ends by these valves, and is exhausted by its own steam-engine and apparatus. These valves, which we will call the separating valves, are opened by the driving carriage, to allow the piston to pass, and are closed after the train has passed. *If the trains are required to be started as frequently as possible, the engines are employed constantly exhausting the pipe; but if a longer period than is necessary to exhaust the pipe be required to elapse between starting the trains, the engines are employed* IN THE INTERVAL *to exhaust large vessels or receivers, which when the train starts are opened to the pipe to assist to obtain the vacuum therein, and to maintain it until the train has passed.*

### DESCRIPTION OF THE PARTS.

In all the figures of the drawings hereunto annexed, which show a method of applying this apparatus to a railway, the same letters indicate the same parts. Figures 1 to 5 inclusive are drawn on a scale of one inch to a foot; 6 and 7 inclusive are drawn on a scale of six inches to a foot. Figure 1 is a plan of the driving carriage, to which the arm of the piston is connected, with the upper part or body removed to show the valve. Figure 2 is a longitudinal elevation of the same, with one side of the pipe removed to show the apparatus for opening the valve, also showing the section of the furnace for the heater. Figure 3 is an end elevation of the same. Figure 4 is a section of the continuous pipe, cut at right angles to Figure 2 at M M, showing the valve open and the manner of attaching the arm of the driving carriage, also the gear for opening the safety valve in the piston. Figure 5 is a side elevation of the end of one of the continuous lengths of pipe showing the communication to the exhausting apparatus and the closing or exit separating the valve. Figure 6 is a transverse section of the continuous pipe, and the frame in which the wheel for opening the valve is fixed, cut at right angles to Figure 2 at *g g*. Figure 7 is the same view as Figure 6, with the valve and projecting cover closed.

A A, The continuous pipe. This pipe is lined with a composition of bees'-wax and tallow similar to that used for sealing the valve. B, the piston, (this piston has two expanding leathers, *n n*, similar to those used in the pistons of air-pumps; one of these leathers is fixed about fourteen

inches in advance of the other, so that no air may leak into the pipe, A, when the piston passes the recess formed for the separating valve *f*,) C, the arm which connects the piston to the driving carriage; D, perch or bar attached to the axles, E, of the driving carriage by the bearings X; F, the trough or groove containing the tallow in which the edge of the valve G is immersed; G G, continuous valve, formed of leather or other flexible material riveted between plates of metal in such a manner that the leather forms a hinge as in common pump valves; the fixed side of this hinge is fastened down by a bar of iron, 2, laid edgewise longitudinally along it, and pressed down on its surface by the screw-bolts and nuts, 3: this bar is kept in its place against the side by the screw-bolts and nuts, 4, as shown at Figures 6 and 7. When thus screwed down, the composition similar to that used in the trough is poured in at the back of the leather. H, wheels for lifting the valve, G G, working on pins in the train T, which is firmly attached to the arm C; I, cover for protecting the valve, G, and the trough from the weather and accidents; J *a*, valve in the piston B, which is opened or shut by sliding it round on its face so as to uncover or cover opening made in the piston; W, a lever attached to a cylinder, P, by a rod, K; the cylinder *p* slides on a key fitted in the piston rod *g*, which prevents it from turning round a pin, P, in the cylinder; P slides in the spiral chase, L, formed in the neck of the valve, J, for that purpose. The valve is opened by pushing the long end of the lever, W, which draws the rod K, and with it the cylinder P, to which it is attached, and thus by causing the pin, P, to move in a right line turns the valve round M, the balance weight to keep the piston B from pressing unequally against the sides of the pipe A A; Y, universal joint to allow the balance weight to act, and also to allow for inequalities in the pipe or rails; N, tube or flue receiving heat and flame from the fire-place, Z. The bottom side of this tube rests on the tallow contained in the trough F. This tube we shall call the heater. O, small rod or universal joint by which the heater, N, is attached to the perch D; *g*, valve working on a hinge, *h h*, for closing the pipe near the end at which the piston enters through, we call an entrance separating valve; Q, Figure 5, valve for closing the other end of the pipe; this we call an exit separating valve; C, lever catching into the stop, *d*, for keeping the separating valve shut or open; *e*, spring for pressing the lever up to the stop, *d;* R *a*, a second lever attached to the lever C by the rod *j*, which should be about thirty feet long; *k*, cam or stud projecting from the perch, D, for opening the valve; *f i*, the rail on which the carriages travel; *l*, the wheels of the driving carriage; W *a*, branch for connecting the pipe A to the exhausting apparatus; this branch should be about thirty feet from the valve; Q, V, wheel attached to the perch D by a spring, *v;* this wheel presses on the valve G; V, special joint between heater and fire-place.

## OPERATION.

In order to put the system into operation the first section of the continuous pipe, A A, between two separating valves, is partially exhausted when the driving carriage is at rest, the entrance separating valve *f*, is opened by an attendant, but when in motion by the cam, R, coming in contact with the lever R, which draws the rod *j* and disengages the lever C from the catch *d*, the valve then being disengaged will open by the atmospheric pressure and fall back into a recess cast in the pipe. The lever is kept up to the catch by the spring *e*, which causes it to catch again when the valve is wide open, and keep it from closing the valve. *f* being opened on one side of the piston, B is exposed to the rarefied atmosphere in the pipes, while the other side receives the full pressure of the ex-

ternal atmosphere; this difference of pressure causes the piston to move forward and draw with it the driving carriage to which it is attached. This carriage as it goes along constantly raises the valve G G, by means of the wheels H, to admit the external atmosphere freely to the back of the piston, and to allow a space for the connecting arm, C; the cover, I, is at the same time lifted by the perch of the driving carriage, as shown at Figure 2; the wheel, *v*, which follows the arm C, passes down the valve, G, ready for the heater, N, which is attached to and follows the driving carriage to re-melt the tallow which has been broken up by lifting the valve G. This heater is kept hot by a fire lighted in the fire-place, Z, the flame and heat from which passes through the tube, N, and the valve is thus resealed and left in a fit state for the approach of the next train. When the train is stopped the damper shown by the dotted lines in that part of the tube at (*b*) is closed, and that in the chimney is opened, which causes the flame to escape at the chimney, *a*, instead of passing the heater, N, and escaping at O. The length of this heater is regulated by the speed at which the trains are intended to travel. When the train arrives near the end of a portion of the pipe, the piston, after pressing the branch *u*, condenses or compresses the air in the remainder of the pipe, which by its pressure opens the valve *q*. This valve may be closed after the train has passed by an attendant.

The movement of the universal joint, Y, is limited so as to be only sufficient for the irregularities of the rails and continuous pipe, but it will not allow the piston to diverge from its line enough to prevent it entering the next portion of the pipe, the end of which is made larger or bell-mouthed to receive it.

When it is necessary to retard the speed of the train, it may be done by a common break or by slightly opening the valve J in the piston by means of the lever W. This admits a portion of atmospheric air from the back of the piston B into the rarefied or exhausted part of the pipe A in front of the piston, and by this means lessens the difference of pressure between the back and front of the piston. When it is required to stop the train with the piston in the pipes, the valve *j* must be opened full. This valve must be of sufficient dimensions to establish an equilibrium, or nearly so, on both sides of the piston, and consequently to destroy the moving power of the train.

In every socket or joint of each pipe a space is left between the packing it contains, as shown at S, Figure 2. This space is filled with a fluid or semi-fluid, which will be drawn into the pipe before any leakage of air can take place, and which may be occasionally replenished.

The composition we prefer is a mixture consisting of three parts tallow and one part bees'-wax; but these proportions may be varied according to circumstances, so long as it forms always a solid substance at the temperature of the atmosphere, and can be rendered partially fluid as above described.

Now that we have described the nature and action of our improved valves, and the application thereof to railways and other purposes, we do not claim the precise size or form of the various parts or the using of the precise materials herein described, but we claim exclusively the method of construction and using valves above described, and combining the said valves in the manner above described herein, for rendering available the application of direct tractive force either on railway or otherwise.

## No. 11.

### CASE[a].

In 1839, letters patent were granted to Mr. Samuel Clegg for a new improvement in valves and the combination of them with machinery.

A copy of the specification accompanies this case.

The improvement therein is represented to consist in a method of constructing and making valves in combination with machinery.

The more immediate use to which the patentee intended the application of the valve was to atmospheric railways, and the object of it was to effect the perfect closing of the cylinders after the passing of the train, and the consequent power to reproduce the vacuum.

All previous attempts in this respect had failed.

The specification in the first place describes the nature and construction of the valve, and then the different parts of an atmospheric railway, and the combination of the valves therewith; and it concludes with the following claim :—" Now that I have described the nature, constitution, and action of my improved valves, and the application thereof to railway and other purposes, *I do not claim the precise size or form of the various parts, or the using of the precise material herein described, but I claim exclusively the method of constructing* and using valves as above described, and combining the said valves in the manner above described herein for rendering available the application of direct tractive force either on railways or otherwise."

The system (described as part of the combination) consisting of a pipe laid between rails, to be exhausted by a pump worked by a steam-engine, was well known previously to Mr. Clegg's patent, as was also an apparatus for travelling inside the pipe, and a valve for covering the continuous opening. These were, however, useless for the purpose described in Mr. Clegg's patent: viz. " Rendering available the application of direct tractive force either on railways or otherwise," from the incapacity of the valve to preserve the vacuum until required to pass the trains. The details also as to shape, and especially as to arrangement, in Mr. Clegg's specification, are widely different from those previously published.

*The valve is altogether new*, except so far as it is made of a material (leather) previously in use for valves of a certain description. The employment of *air-vessels as reservoirs of power* is also new, and considered to be extremely advantageous, although not indispensable to the working of the combination.

Mr. Clegg's object in procuring the patent was *to protect the valves and the means by which they are made available for the purpose pointed out;* but he is apprehensive lest, either by the title or specification, he may have claimed *too much,* and endangered the patent.

Your opinion is requested :—

1st. Whether the title of the patent is too large with reference to the limited object to which the valves are declared to be applicable, or with reference to the particular machinery with which they may be combined, as explained by the specification; and if you should be of opinion that the title is objectionable, you are requested to point out what alteration should

[a] The Italics in this " Case " are as in the original MS.

be made in it. The following title has been suggested as an improvement, and as an amendment within the Act: viz. Improvement in such valves as may be combined with machinery, and in the combination thereof with machinery for traction on railways.

2nd. Whether the ***whole apparatus*** of the railway, ***including the valves***, is covered by the patent, or merely the valves and so much of the machinery as is necessary to make them available for the railway.

3rd. Should any improvement in the machinery in combination be not covered by the patent, could they be patented by any other person, the specification being the only mode by which they have been published?

1st. The title of the patent is, perhaps, not wholly free from objection, but I think it is not too large; it ***is*** an ***improvement*** in ***valves*** if it be an improvement in ***some***, that is in a ***class*** of valves.

I think ***that*** is sufficient. The Court of Queen's Bench lately decided otherwise, and their decision is now before a Court of Error. I should not advise any alteration unless that judgment be confirmed. In that case, I should not advise the alteration as suggested, but as I have altered it above.

2nd. I think the whole apparatus is not covered by the patent, but merely the improved valve and the combination.

3rd. Neither the patentee nor any other person could take out a patent for improvements not covered by the claim, but appearing in the specification.

(Signed) FRED[K] POLLOCK.

TEMPLE. 16TH JUNE, 1843.

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After much procrastination, I, with some difficulty, got a copy of the above case and opinion, which although put exparte, and manifestly so shaped as to be likely to bias or mislead the views of counsel, yet seemed to me quite in my favour. For it clearly affirmed that the patent merely covered the improved valve and the combination, and therefore did not cover any exhausting apparatus, of whatever sort or however worked; and it was manifest that the sentence in the specification which proposes to use the engines to exhaust reservoirs ***in the intervals between trains***, under certain circumstances, was no publication of my invention for their ***constant and continuous use at all times, both during the intervals of trains and during their transit, or in circumstances where there were no intervals; in a word for abandoning all exhaustion of the main directly by the air pump***. much less of the various other arrangements for exhaustion or modes of working at the first time proposed in my three Reports. A tedious negotiation hence arose as to taking the proposed joint-patent—which was, after the waste of nearly a year, closed by the following correspondence.

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No. 12.

DUBLIN AND KINGSTOWN RAILWAY.
48, Westland Row,
10th August, 1843.

MY DEAR ROBERT,

I have had a conference with both the Samudas yesterday afternoon; the result is, that we are not disposed to take out any further patents at present.

Yours very truly,
J. PIM, JUN.

ROBT. MALLET, ESQ.

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No. 13.

RYDER'S ROW, DUBLIN.
30th August, 1843.

DEAR SIR,

I was favoured with your note of the 10th inst. just before leaving town, from which I have been very much absent since, or I should have sooner acknowledged it.

In your and Messrs. Samuda's at length declining to take out a patent for my discovery or inventions as to the mode of working the Atmospheric Railway system, I have chiefly to regret that so many months' delay and such legal formalities have passed unnecessarily, before favouring me with a conclusion which, for aught I have seen or have been informed of by you, could have been as readily communicated several months since.

The progress of this lengthy negotiation has, however, had this value, that it has evidenced, beyond reach of future doubt, my rights as a first inventor, and I believe equally so the power of taking out a patent. Of the value of these inventions you were yourself, as well as Dr. Robinson and Mr. Bergin, ardent assertors, and up to this time I have found nothing in the shape of argument advanced to the contrary by any one.

I now, therefore, as you decline to patent without assigning any reason, propose what you yourself first suggested to me in the event of a patent not being taken early in this business; namely, to sell my rights in the invention to you, for such consideration as may be agreed upon.

I would beg to be favoured with your early reply, which, from the complete information already possessed by all parties upon every point of this subject, need not, I presume, involve much trouble or time in concluding, whether affirmatively or negatively.

I remain
Yours very truly,
ROBERT MALLET.

---

DUBLIN AND KINGSTOWN RAILWAY.
48, Westland Row,
11th Sept. 1843.

No. 14.

MY DEAR ROBERT,

I have duly received your letter of the 30th August, to which I would at once have replied, but I wished to have an opportunity of consulting *both* the Messrs. Samuda.

The result of our conference is, that we are not disposed to purchase your invention, and for this plain reason, that we believe it was not only previously invented, but patented by Messrs. Clegg and Samuda.

I confess I am utterly at a loss to conceive on what grounds you conclude that it has been evidenced, beyond reach of future doubt, your rights as a first inventor, and you believe equally so, the power of your taking out a patent. My conclusions, fortified by the opinion of Sir Frederick Pollock, (of which you have a copy,) are diametrically opposite.

I am
Yours truly,
J. PIM, JUN.

ROBERT MALLET, ESQ.

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No. 15.

RYDER'S ROW,
13th Sept. 1843.

DEAR SIR,

I am favoured with yours of the 11th inst. in reply to mine of the 30th August, and which would have needed no rejoinder from me if confined to a declension of my last proposition.

Sir F. Pollock's opinion, though given ex parte instead of on a mutually agreed case, as promised me, I do not dispute. Whatever appears on the face of Clegg's specification as to exhaustion by means of reservoirs, that opinion declares ***not covered*** by his patent, and now ***not patentable by any one***, because already published: to such I make no claim of course; but my inventions, as communicated to you, go much further than any thing Clegg described in his specification, and to all not therein described my rights as first inventor remain inviolable, unless divulged by any one to whom they were in confidence communicated.

Remembering, therefore, that my communications were made to you, and sanctioned being made by you to certain others, under a promise of secrecy, and so that (to use your own words upon the occasion) " should you and those you acted with not take out a patent, I should be left in the same position as when our negotiation began," I would ask, am I to conclude that you now consider yourself absolved from this promise? as your note appears to me by implication and for the first time, to deny to me not only ***all*** right as an inventor, but the very fact of my having communicated to you much more, touching the use of these reservoirs or vacuum vessels than you before knew, or than is stated in Clegg's specification. Favour me with your early reply.

I am, dear Sir,
Yours truly,
ROBERT MALLET.

JAMES PIM, JUN., ESQ.

---

No. 16.

DUBLIN AND KINGSTOWN RAILWAY.
Dublin, 5, Westland Row,
20th September, 1843.

DEAR SIR,

I have your letter of the 13th, requesting to know if I now consider myself ***absolved*** from a

*promise* which you state I made you; and you profess to give the very words that I used on the occasion.

I have yesterday yours of the 19th, reminding me that I have not replied to the first; I confess that I reply with reluctance, conceiving the inquiry to be made in a peculiarly offensive manner. I believe that you are entitled to all the credit and all the rights of an inventor, *except* priority, to which, in this instance, I believe you have no claim whatever.

You state having communicated to me much more than I before knew touching the use of the reservoirs; this is quite true, for *at that time* I knew nothing whatever about them; but you must recollect that when you first described your invention to Mr. Samuda, he at once stated that the same thing had been discussed between him and Mr. Clegg, and that, to the best of his belief, it was in the specification of their patents.

A copy of the specification was soon after obtained and shown to you, and which, in my opinion, ***should have set the matter at rest***, your invention and its uses being there clearly and substantially described; and I am further of opinion that any attempt to patent such reservoirs ought to be resisted by the patentees.

I believe your secret has been kept by me and the parties to whom you allude, except so far as the publication of the specification.

As far as I am concerned, this letter must close our correspondence on this matter.

I am
Yours, &c.,
JAMES PIM, JUN.

ROBERT MALLET, ESQ.

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22nd Sept. 1843.

DEAR SIR,

I have yours of the 20th inst., and have no intention of prolonging our correspondence on its subject beyond the present, in which I wish to assure you that nothing was further from my desire than to give offence in my letter to you of the 13th, and if by any unhappy expression I have done so, I regret it. A very important part of my letter seems to have escaped you, or at least is not noticed in your repetition of the passage.

I affirm that I communicated to you not only more than you knew before examining Clegg's specification, touching the use of the reservoirs, but more than his specification describes in relation to them or their uses; neither Samuda nor any one else ever professed, in my hearing, to have any information on this subject (except what is therein expressed) until after my communications to him and to you, and even then, and long since, he expressed his utter disbelief of any advantage resulting either from the use of reservoirs between the times of transit of trains as alone proposed by Clegg's specification, or from their further uninterrupted use as first proposed by me.

A *part* only, therefore, and that the least important, of my inventions and their uses, is "clearly and substantially described in that specification;" to all that is so I make no claim whatever as *first* inventor, but to all beyond that which I have communicated I do; (and aside from any mercantile views on the subject) I have thought, perhaps erroneously, that less

disposition has been latterly evinced to admit my right or credit as first inventor than I am entitled to.

I would wish, however, this correspondence should close without unfriendly feelings on either side.

And am, dear Sir,
Truly yours,
ROBT MALLET.

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To render it intelligible to the reader how it has been that my inventions, though admitted of value by the parties interested in the Atmospheric Valve Patent, have neither been patented nor, as yet, brought into use, I have found it inevitable to print at tedious length the foregoing documents, by comparing which with my Reports 1, 2, and 3, (copies of which I would here state were handed to Mr. Bergin early in 1843,) it will be plain—that neither Clegg nor Samuda ever saw the real and important value of the reservoir system of exhaustion until I pointed it out.

That they never contemplated my invention at all—which consists in ***the constant exhaustion out of reservoirs which shall at intervals share their vacuum with the atmospheric main on communication being made between them;*** whereas what the patentees seem to have proposed as described in their specification was alternately to exhaust the main itself, immediately previous to and during the transit of trains, and in the intervals between the two trains to exhaust reservoirs, which, when the trains started should assist to obtain the vacuum in the pipe, and maintain it until the train had passed. In a word the use of reservoirs, as far as noticed in Clegg's specification (Appendix, p. 58), is only possible where the transit of trains is ***not continuous,*** i. e., where there is a greater or less interval of time between each.

My propositions, on the contrary, first demonstrated the possibility and the advantages of using reservoirs or vacuum vessels, even where the traffic ***is unceasing, and of never exhausting from anything but the reservoirs*** (see pages 13, 14, and 20). Any one who has understood the views of my Reports 1 and 2, will at once perceive that the most important and striking advantages of my system are altogether lost (and indeed were never discovered or thought of) in this partial and incomplete notion crudely thrown out in Clegg's specification; and which perhaps accounts for Mr. Jacob Samuda's having fallen into the mistake of trying to show that my method was valueless.

It is not my object here to make any comment upon the circumstances of my negotiation with the atmospheric patentees; the publication of which has merely been "an inseparable accident" in my establishing my own priority of invention. Those acquainted with Patent Law will see that the owners of Clegg's patent for the long valve and combined apparatus were enabled by means of it to place a bar to any use I alone could have made of a patent for my invention, if taken out after successful opposition to them, unless I could also have used it with a valve not theirs, and they calculated apparently upon being able, at a future time, without any joint patent, to derive all the advantages my communications offered;—if this were their policy, however unworthy, they were not mistaken.

*Αἰσχρὸν τό γ' αἰσχρὸν κἂν δοκῇ κἂν μὴ δοκῇ.*

Such was the first claim made to anticipation of my inventions—the right to use these has now become public property; but until another long valve than Clegg's is brought into use, the owners of his patent must have more or less a monopoly of them. As, however, valves for the atmospheric main are already or doubtless will be proposed better than Clegg's and less costly, the time cannot be distant, when the atmospheric system with the advantage of my method of exhaustion will be free to the public to use.

At subsequent periods several of the methods of exhaustion, &c., contained in my Reports have been reinvented and published as original by other parties. Thus, in August, 1844, a Mr. Roberts, of Cornwall, is stated to have exhibited at the Royal Cornwall Polytechnic Society, at Falmouth, a plan of exhaustion, by reservoirs, which appears similar to mine, (see Mining Journal, 31st August, 1844,) and in the month of April last (1845), a Mons. Arnollet, a French engineer, presented to the Academy of Sciences at Paris a memoir descriptive of the same method, in which he appears to be quite alive to its importance; and upon which memoir, and therefore upon my invention, M. Arago has given a highly favourable report, and thus stamped with his authority its value, (see Comptes Rendus and Mining Journal, 26th April, 1845.)

The method of exhaustion by direct condensation of steam has been reinvented within a year or so by Mr. Naysmith, of Patricroft, near Manchester, who has patented an arrangement for the purpose, (sealed October 22nd, 1844, see Repertory of Arts,) which differs in no essential particular from mine as described in my Report No. 3, and published prior to the date of his patent.

Messrs. Samuda have recently taken a patent (sealed 30th April, 1844) for some trifling improvements in arrangement for obtaining vacuum in reservoirs by the descent of a column of water, (the Torricellian plan,) and a Mr. Aitken has patented some such arrangements. These methods are also noticed in my Reports; but I am bound to remark that the first notice of the general principle of obtaining vacuum by water was published by Jacob Samuda, in his pamphlet descriptive of the Atmospheric Railway, (Weale, London, 1841,) page 7. The method itself is therefore free to the public to use, without reference to subsequent patents as to details.

ROBERT MALLET,

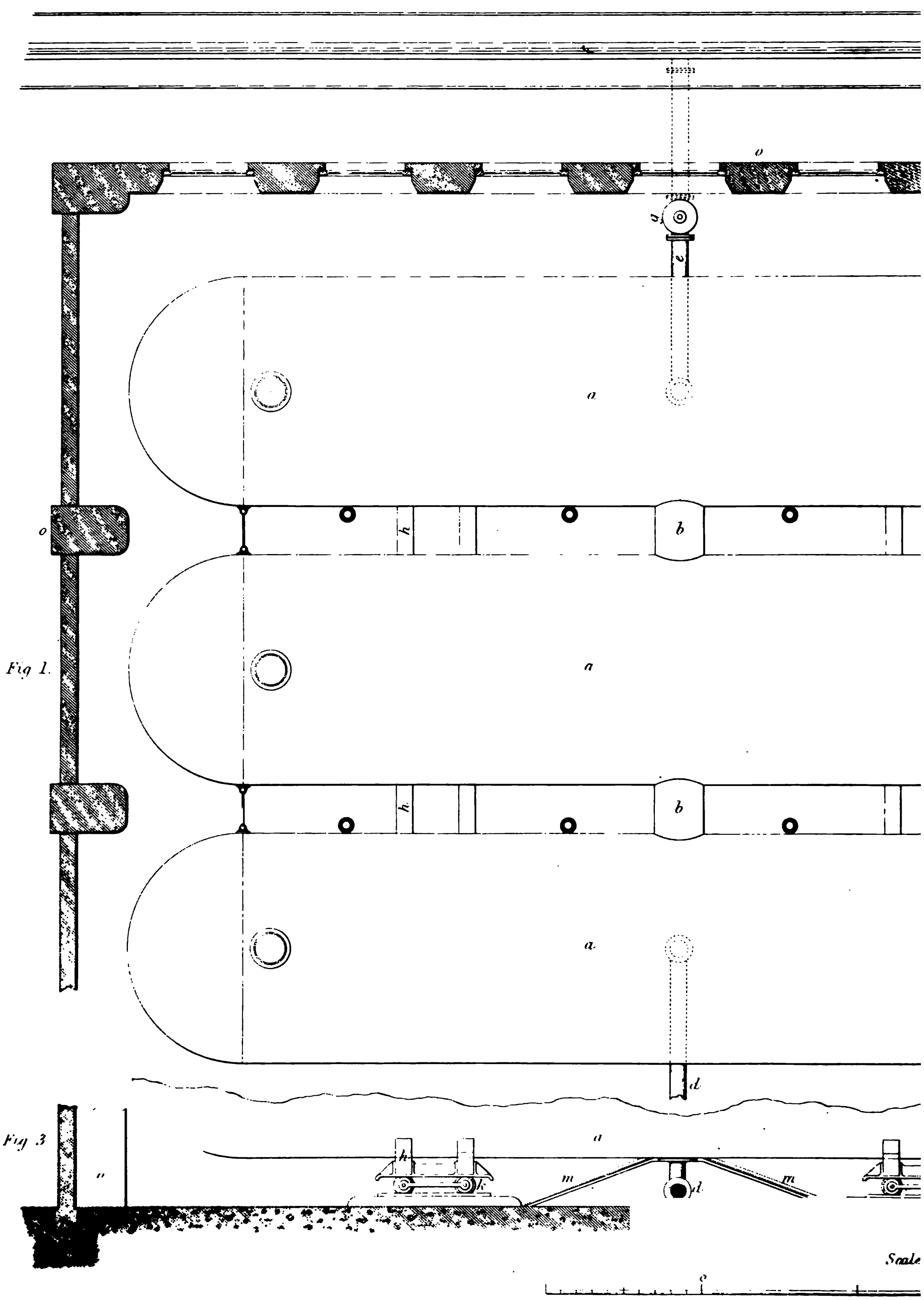
Mem. Inst. C.E.

10th June, 1845.

*Vacuum Vessels t*

Fig 1.

Fig 3

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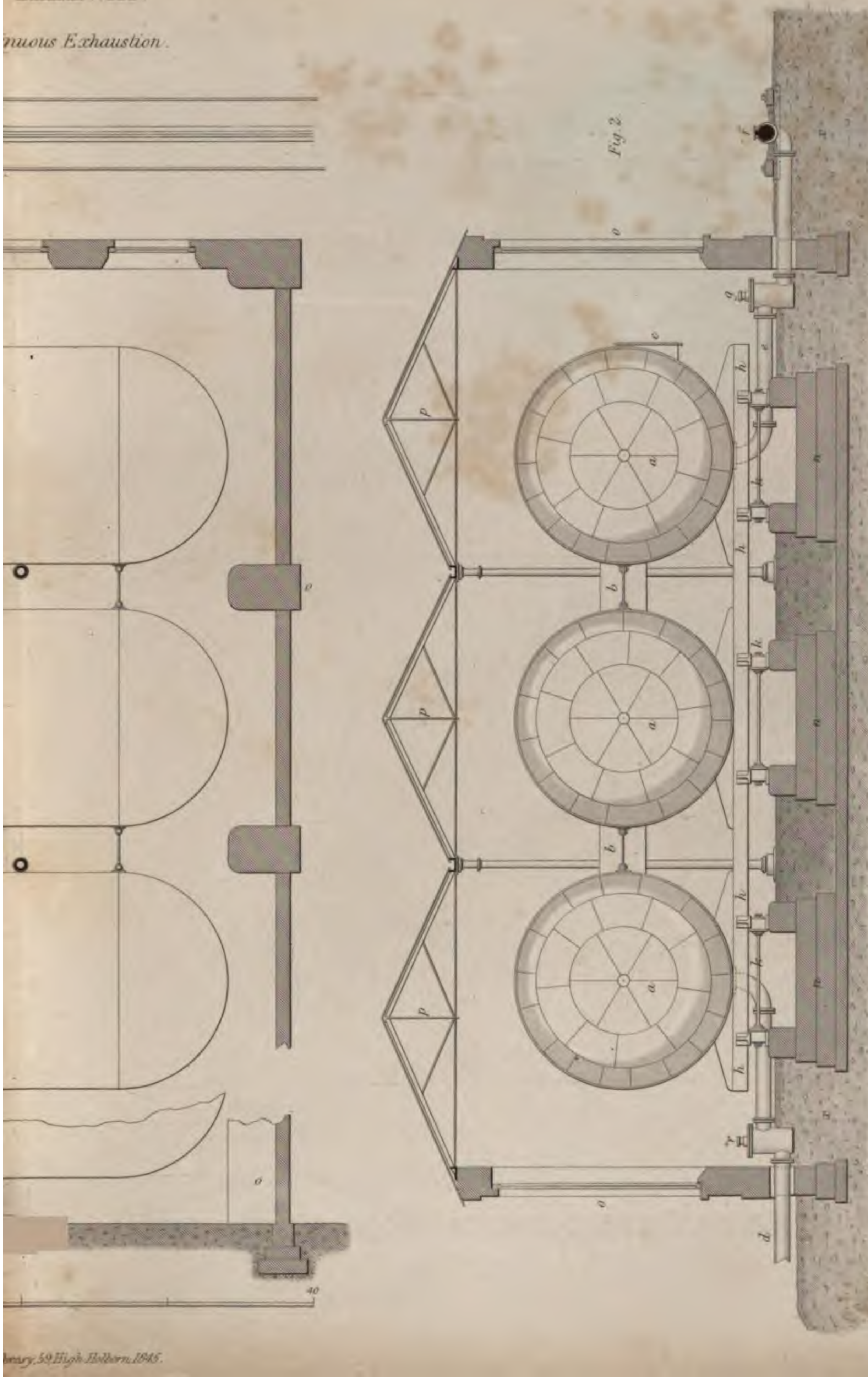
John Weale Arch

RAILWAY.

...nuous Exhaustion.

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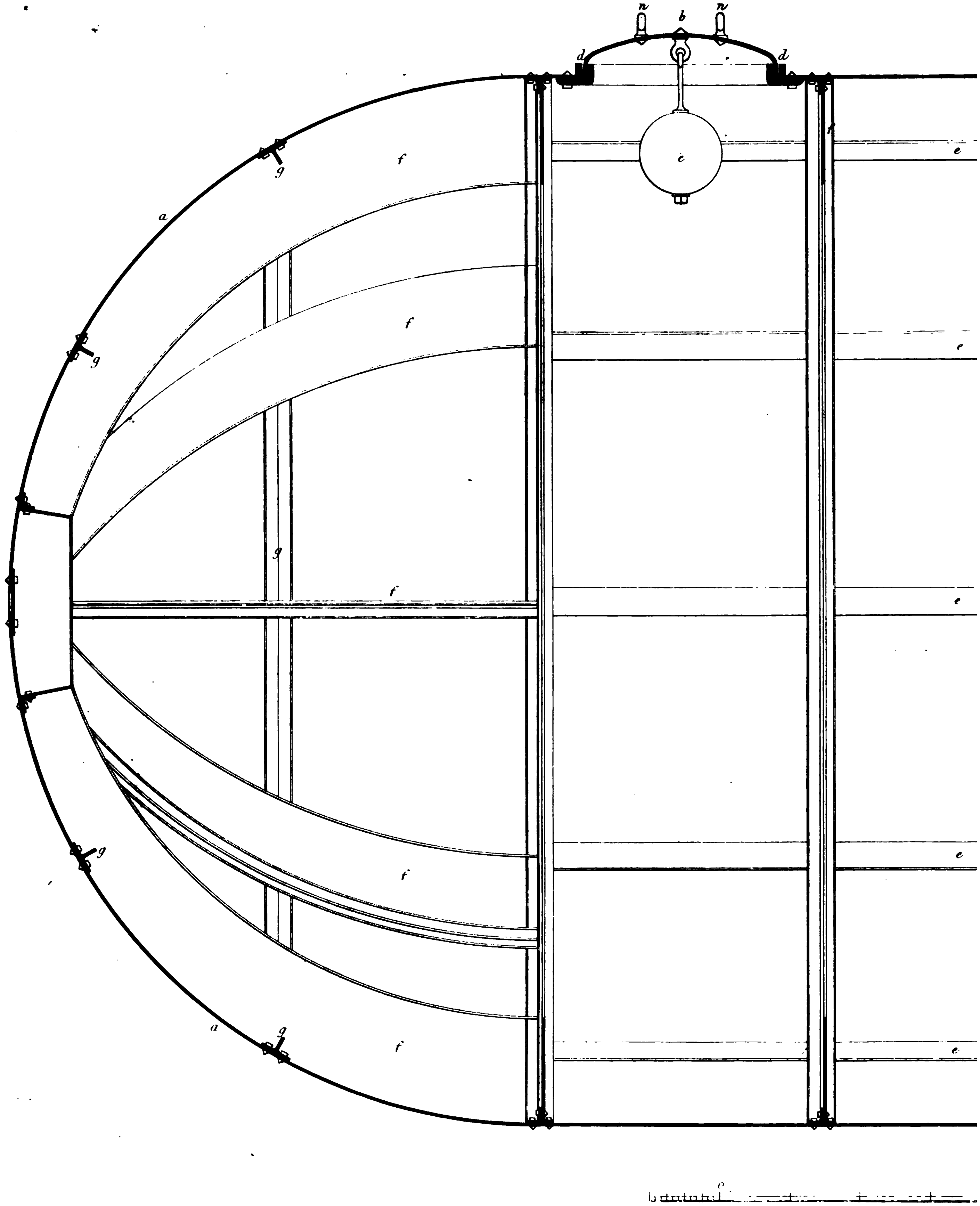


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John. Weale, Arch

Plate II.

RAILWAY.

f Vacuum Vessels.

Fig. 1.

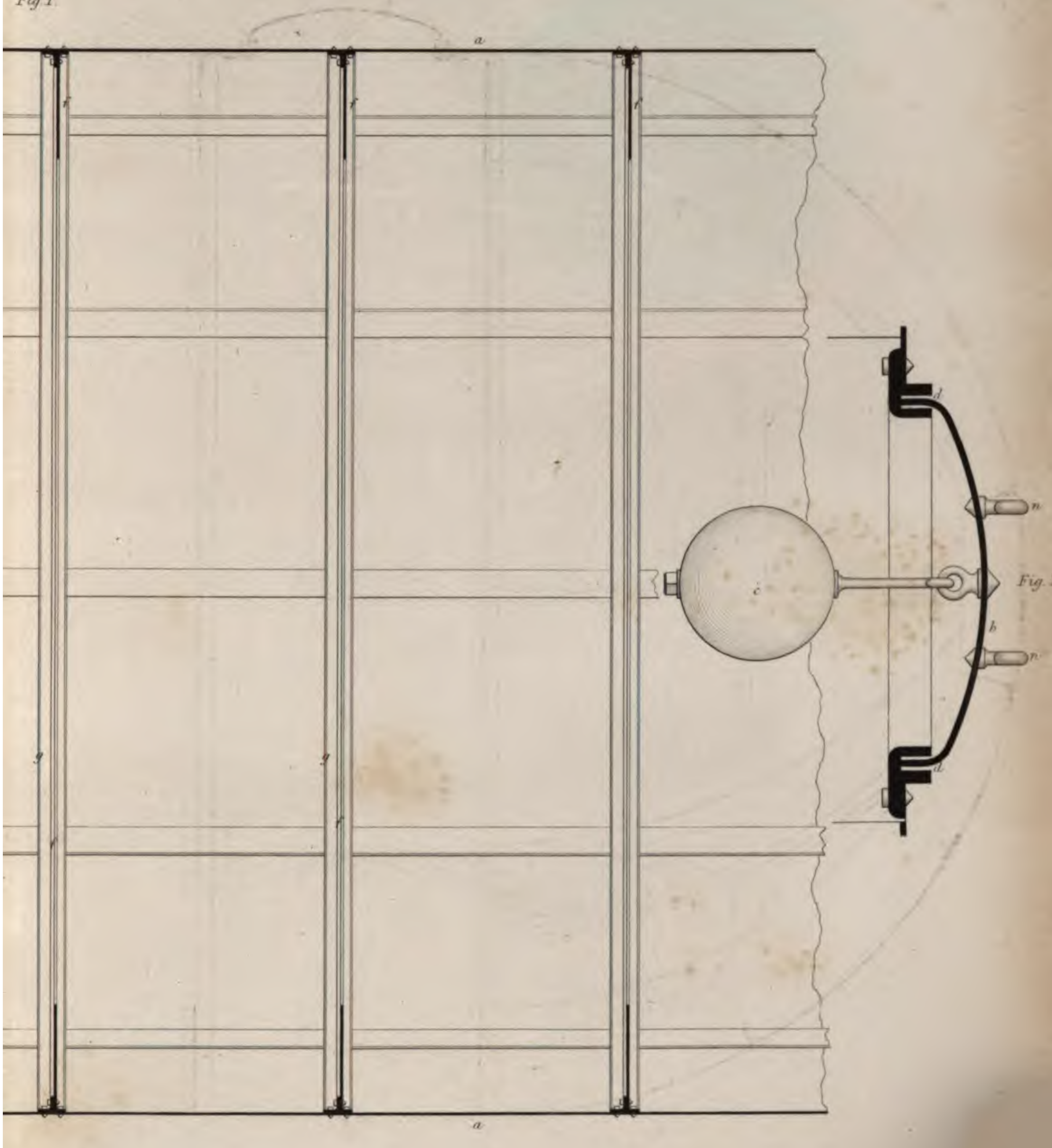
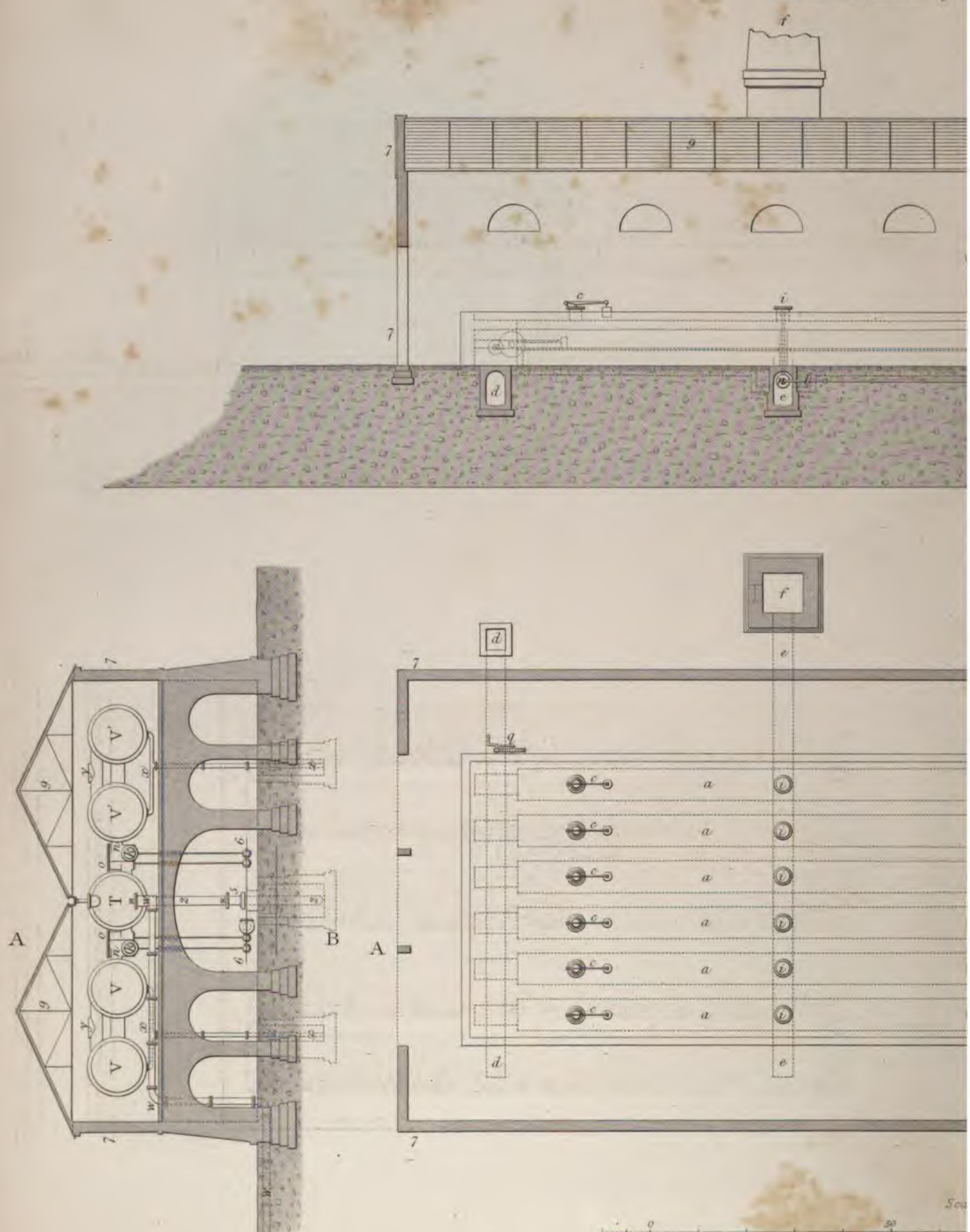



Fig. 2.


nary 59 High Holborn, 1845.

ATMOSPH

*Vacuum Apparatus by t*

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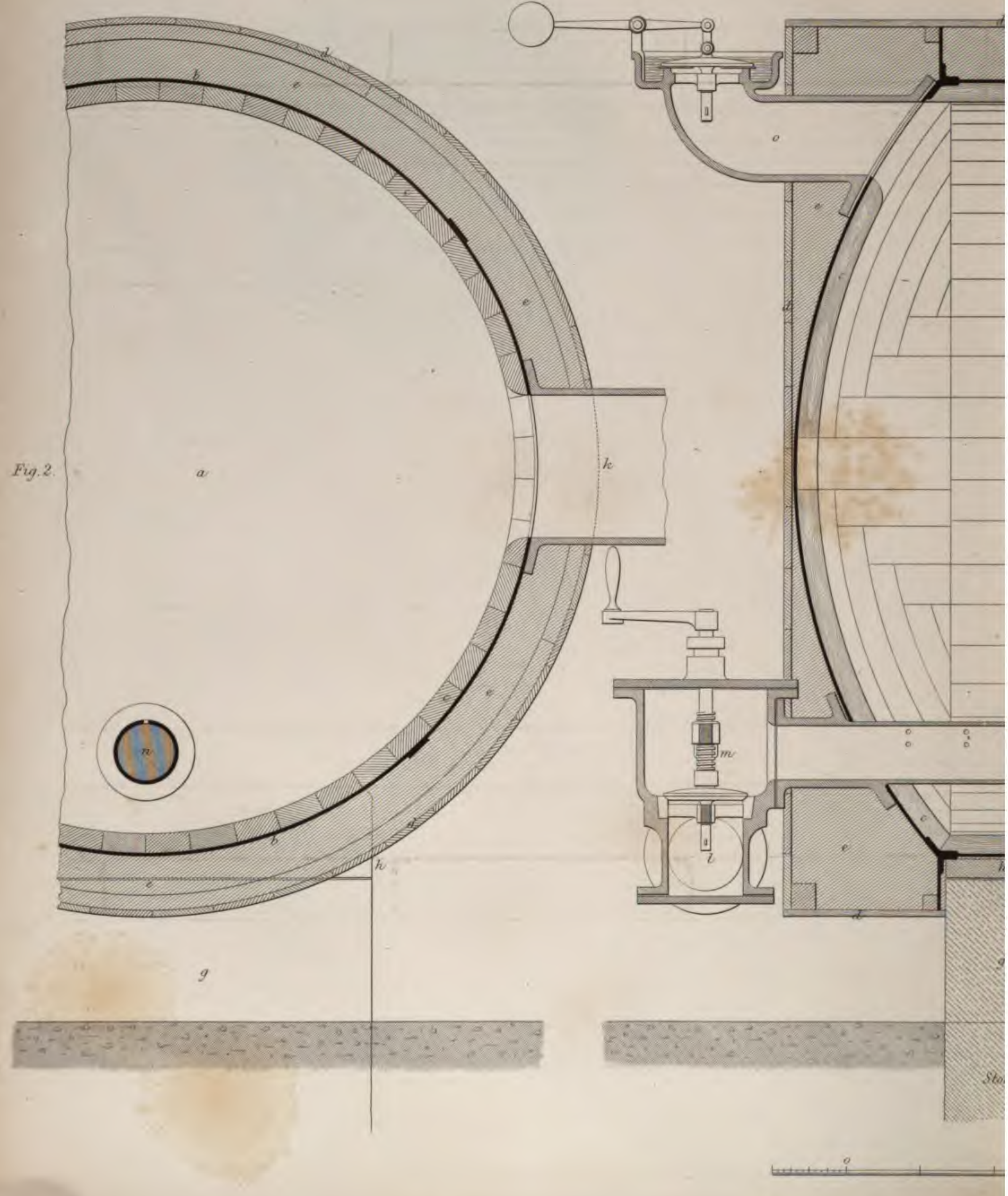
*Details of Construction of Condenser*




del.

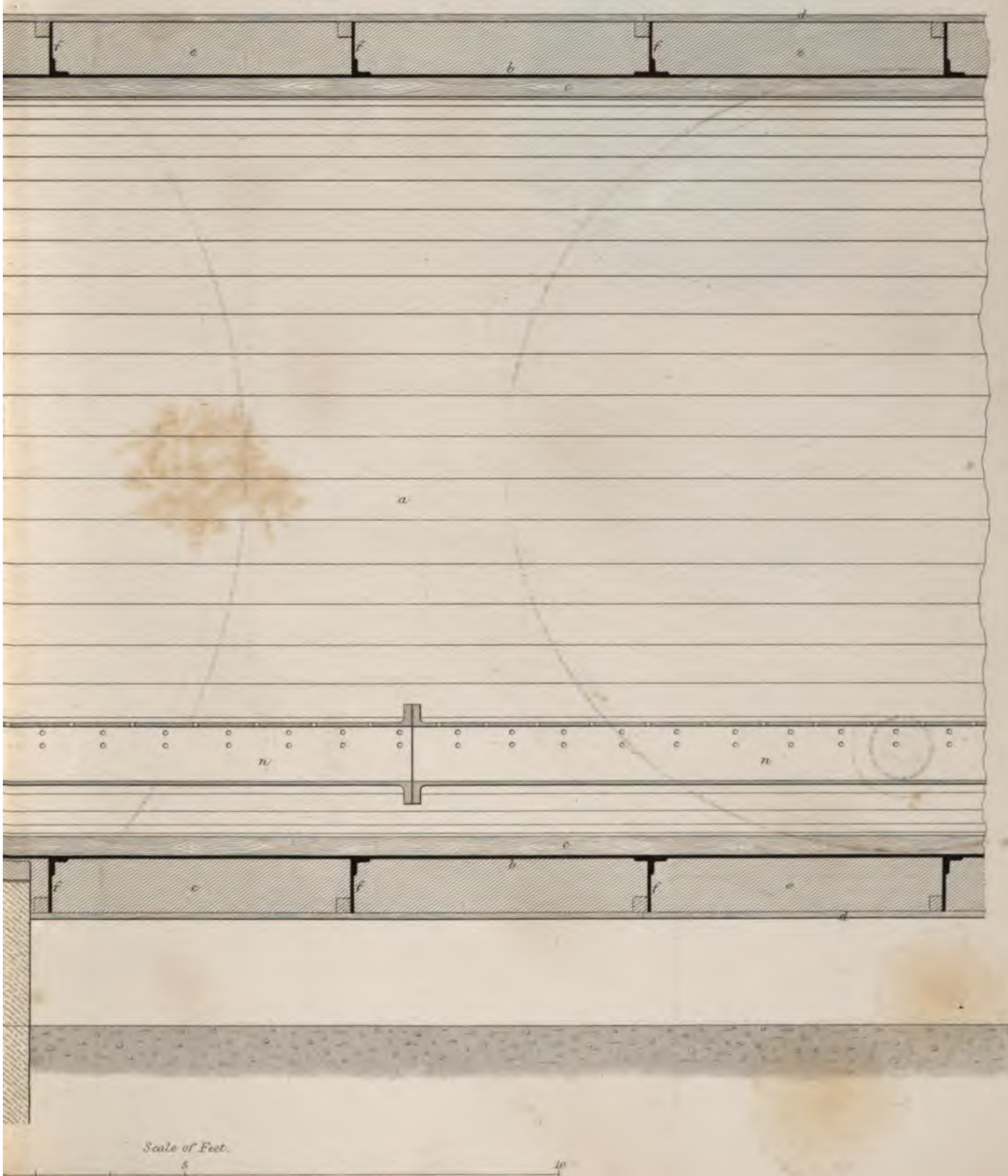
John Weale, Architect

Plate IV.

IC RAILWAY.

for Exhaustion by Direct Action of Steam.

Fig. 1.



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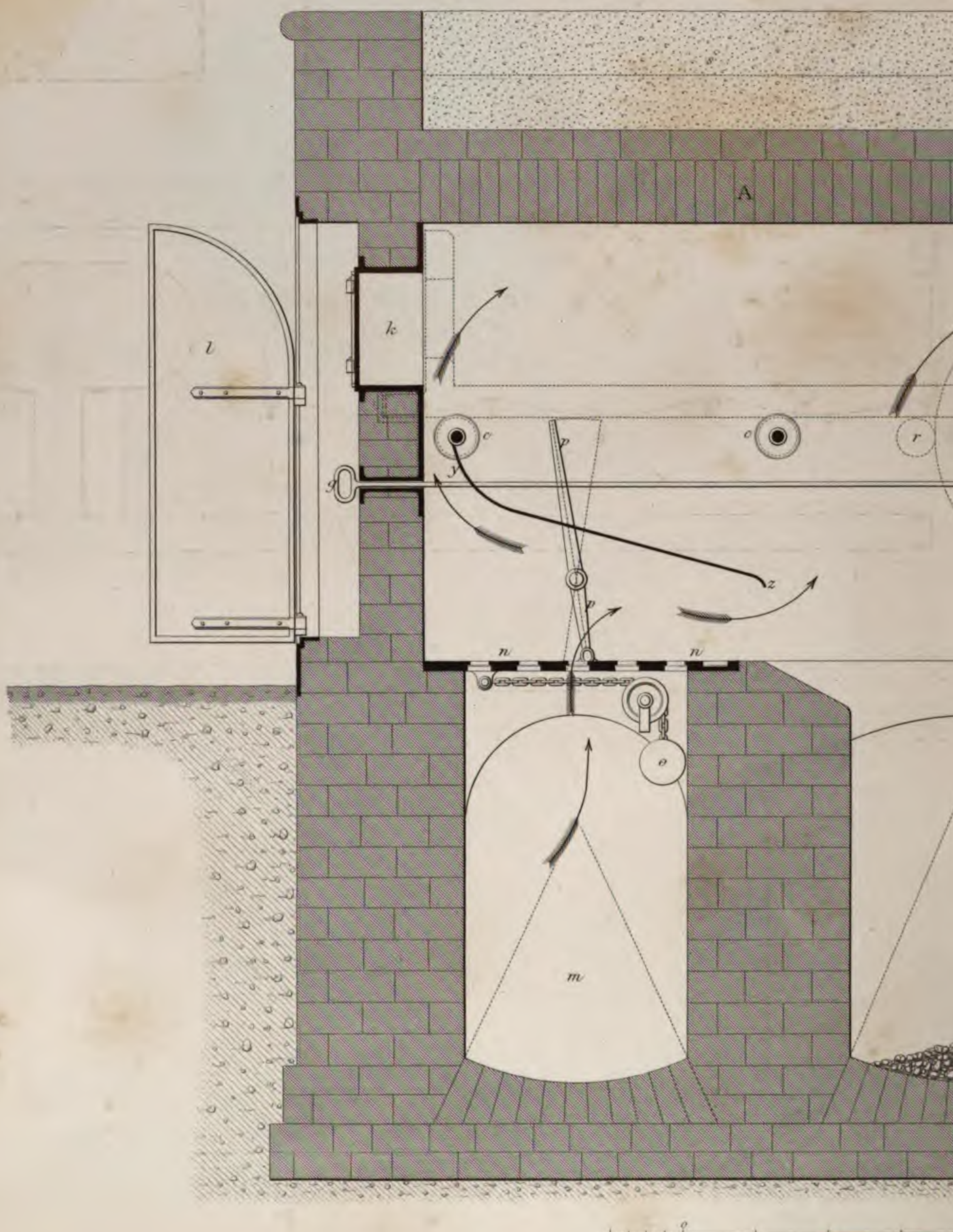
*Details of Construction of Steam Boi*

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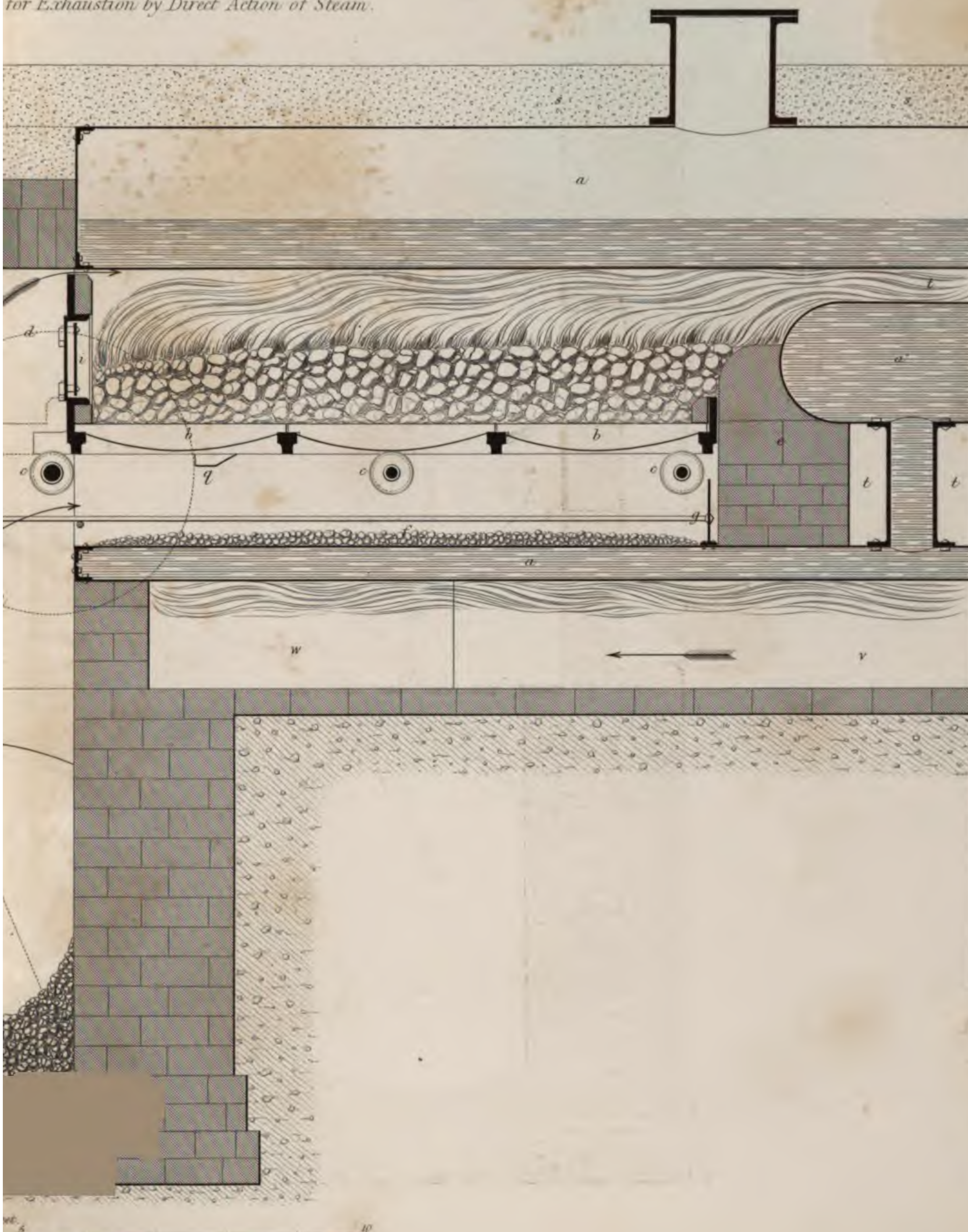
John Weale, A

RAILWAY.

for Exhaustion by Direct Action of Steam.

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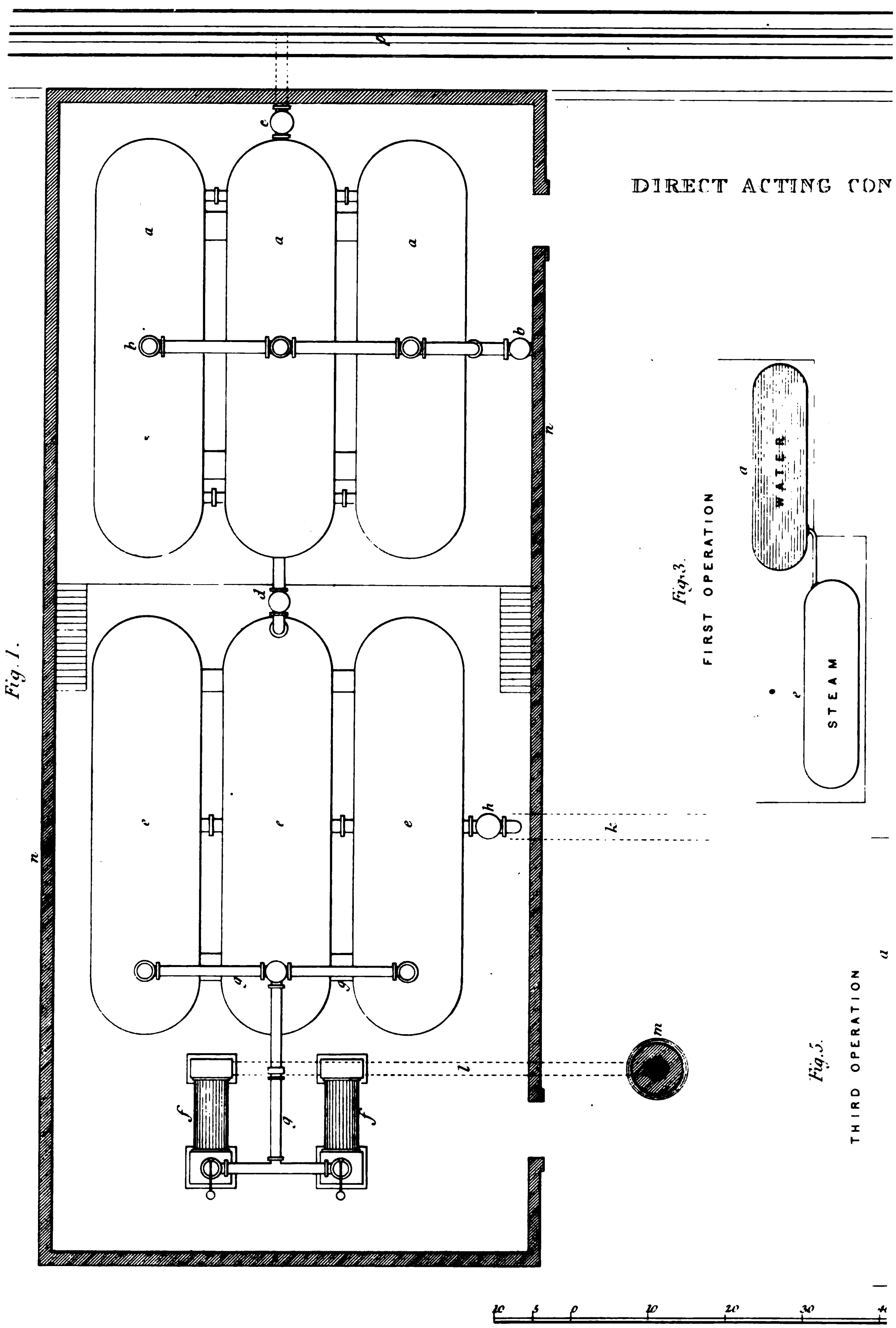



R.Mallet. C.E. del.

London. Published by Joh

# THE TORRICELLIAN METHOD OF
## OBTAINING VACUUM FOR
# ATMOSPHERIC RAILWAYS.

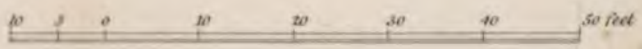
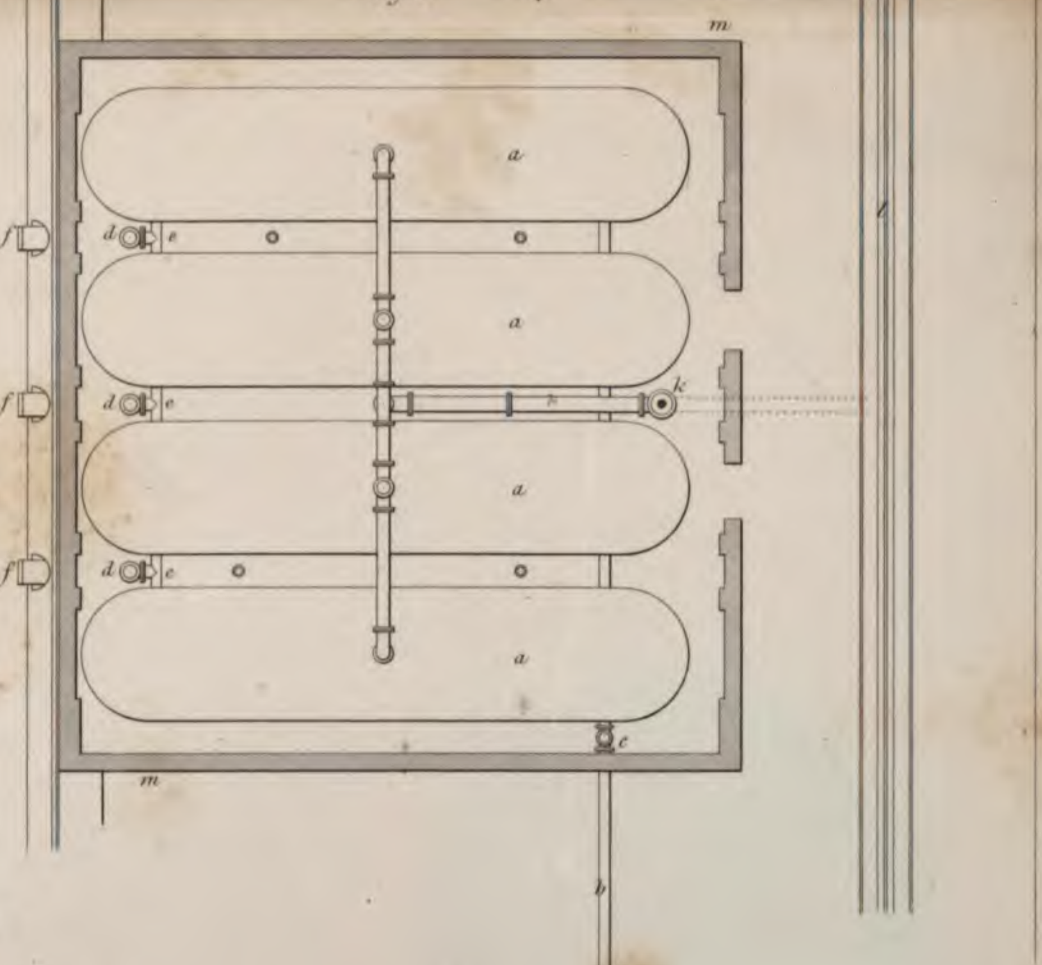



Fig. 1.



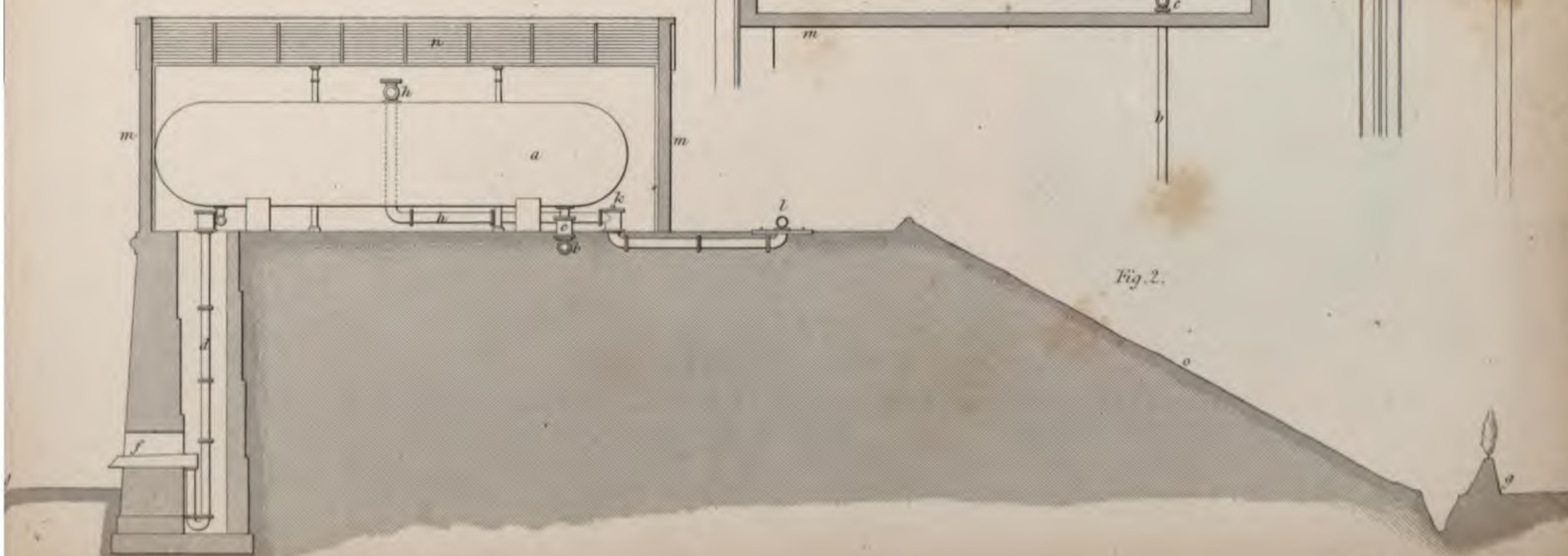




Fig. 2.

B. Mallet, C.E. del.

London. Published by John Weale, 59, High Holborn, 1845.

MR. MALLETS IMPROVED ATMO

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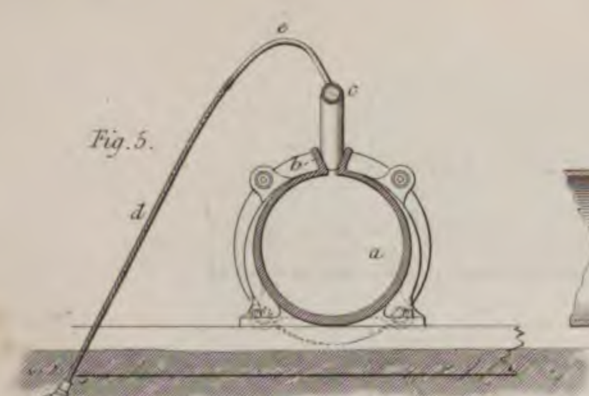
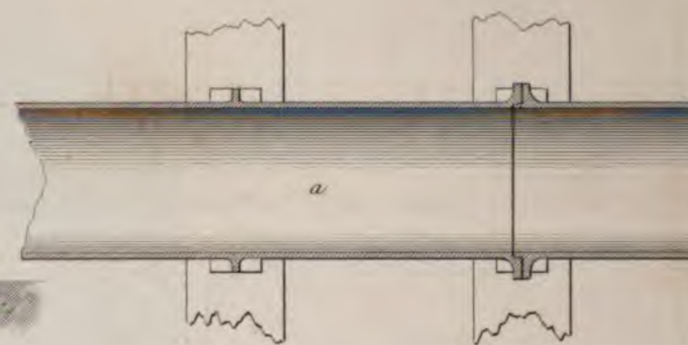



Fig. 5.

TRANSVERSE SECTION VALVE RAISED.



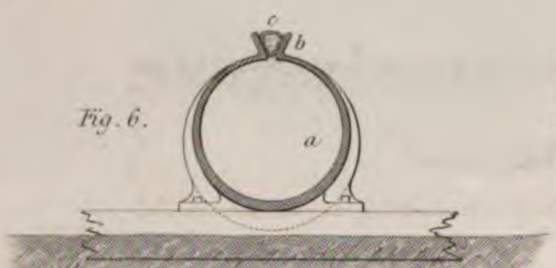
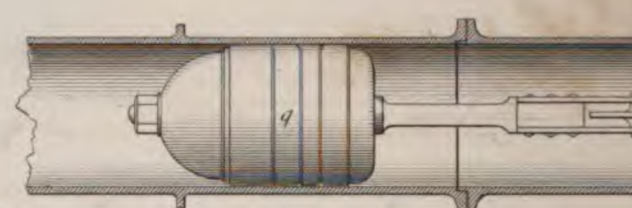




Fig. 6.

TRANSVERSE SECTION VALVE CLOSED.

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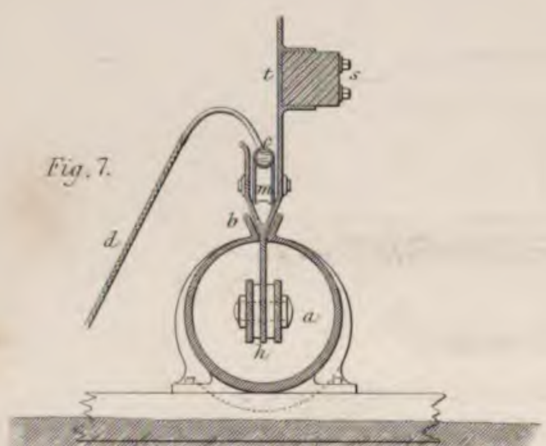
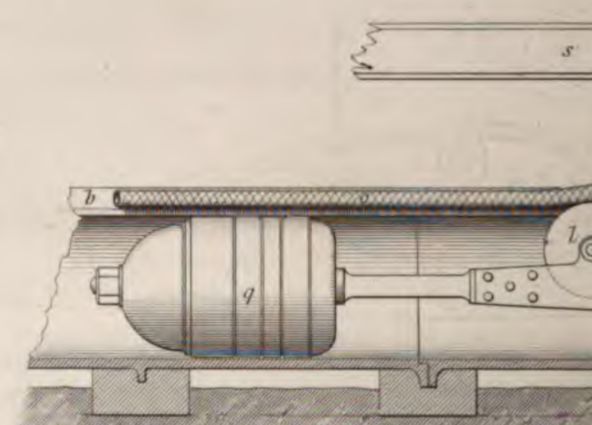



Fig. 7.

TRANSVERSE SECTION THRO' A B.

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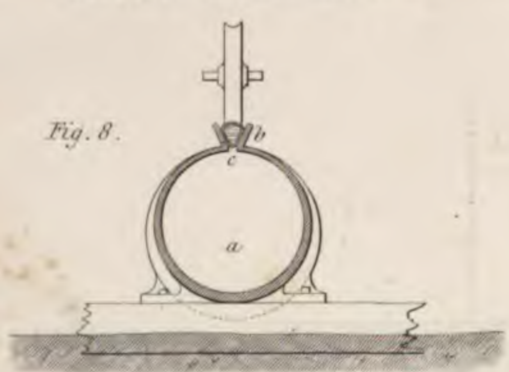
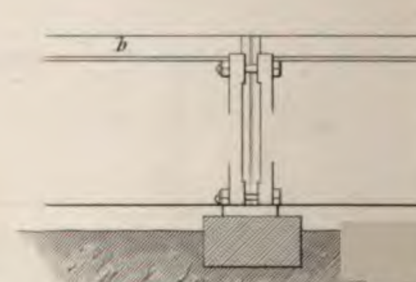



Fig. 8.

TRANSVERSE SECTION THRO' C D.

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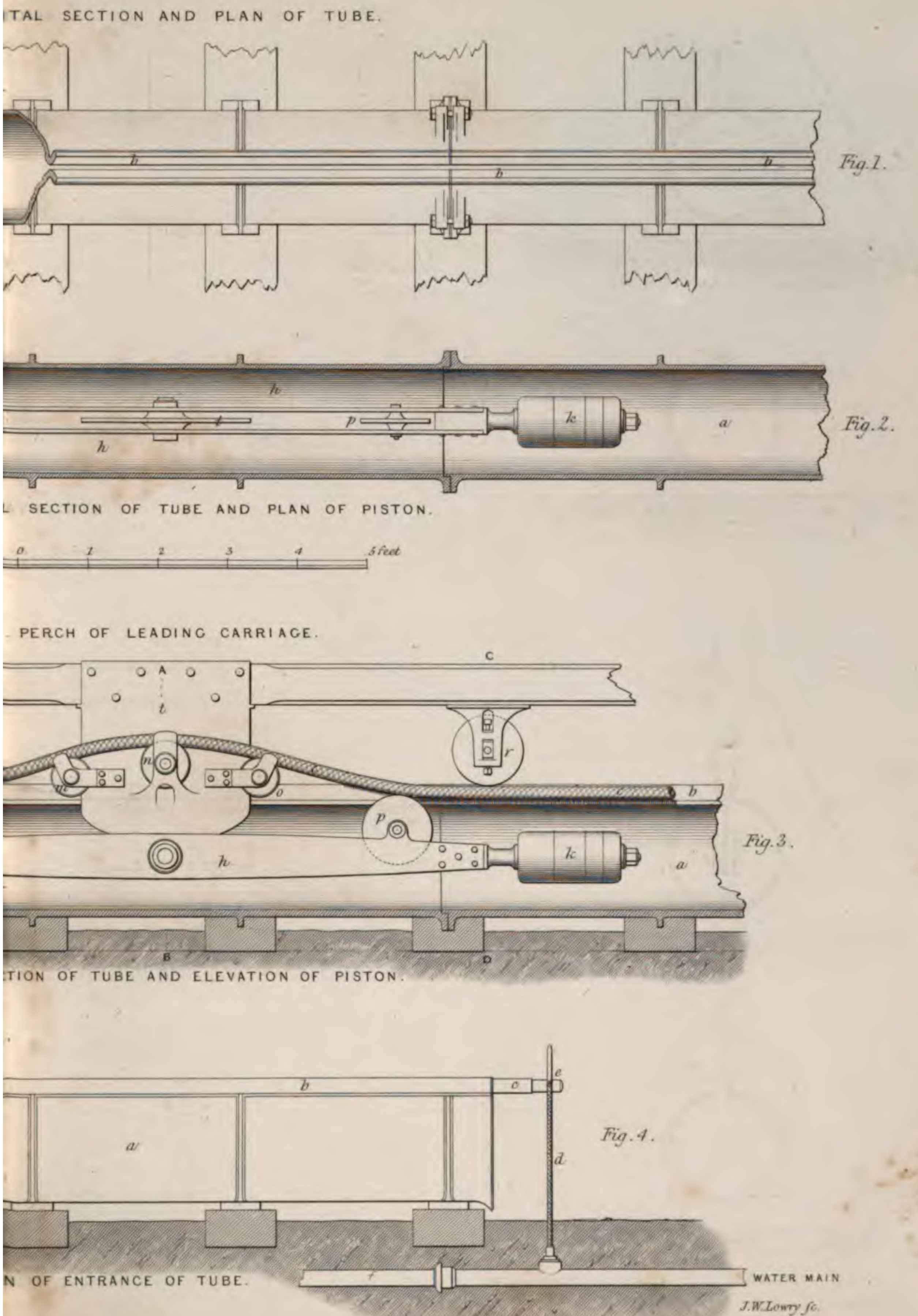
R. Mallet. C.E. del.

London. Published

HERIC RAILWAY VALVE & MAIN. Plate VIII.




Veale 59 High Holborn 1845.

Plate IX.

# M.R MALLET'S IMPROVED ATMOSPHERIC RAILWAY.

VALVE & MAIN SECTION _ HALF SIZE.

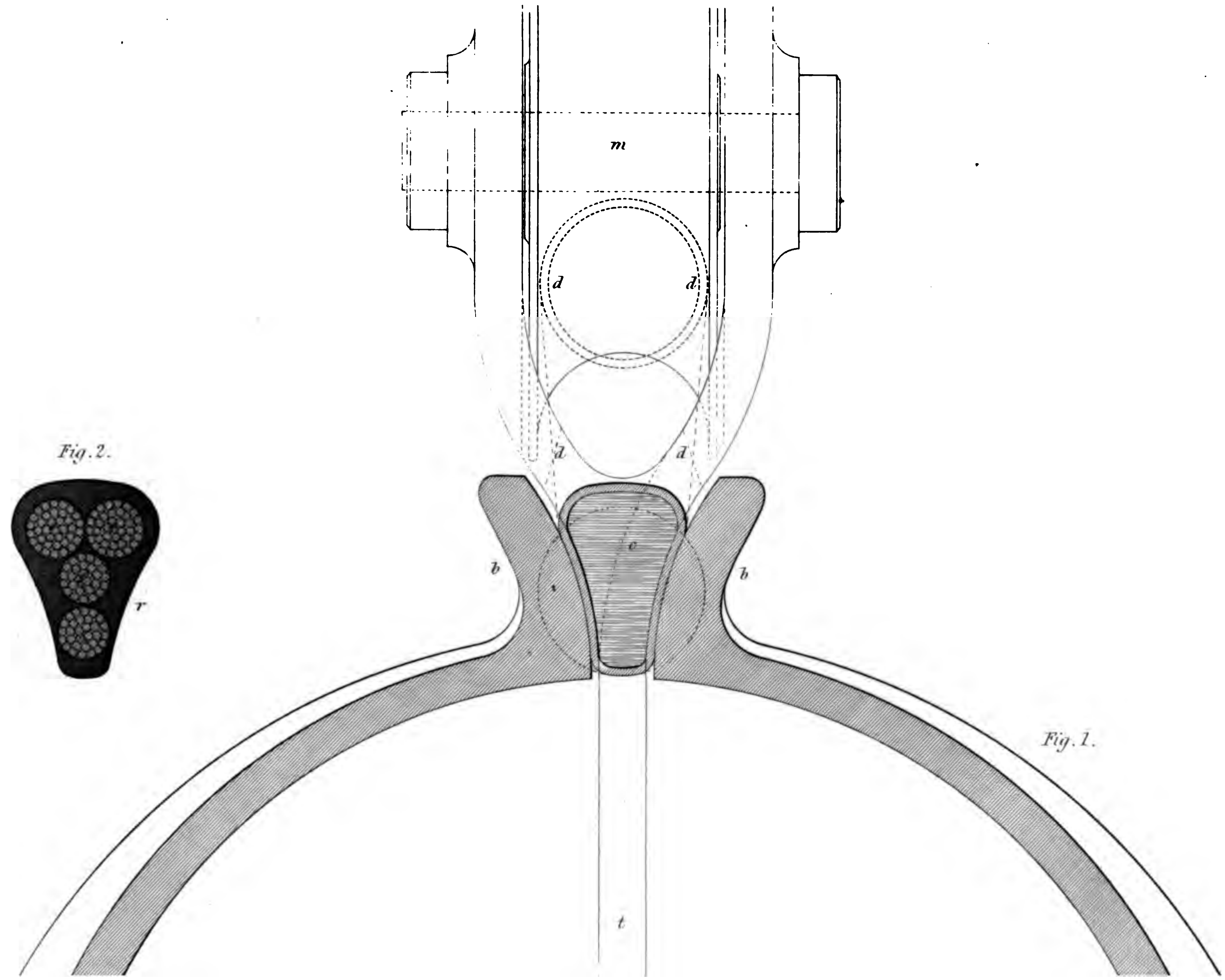
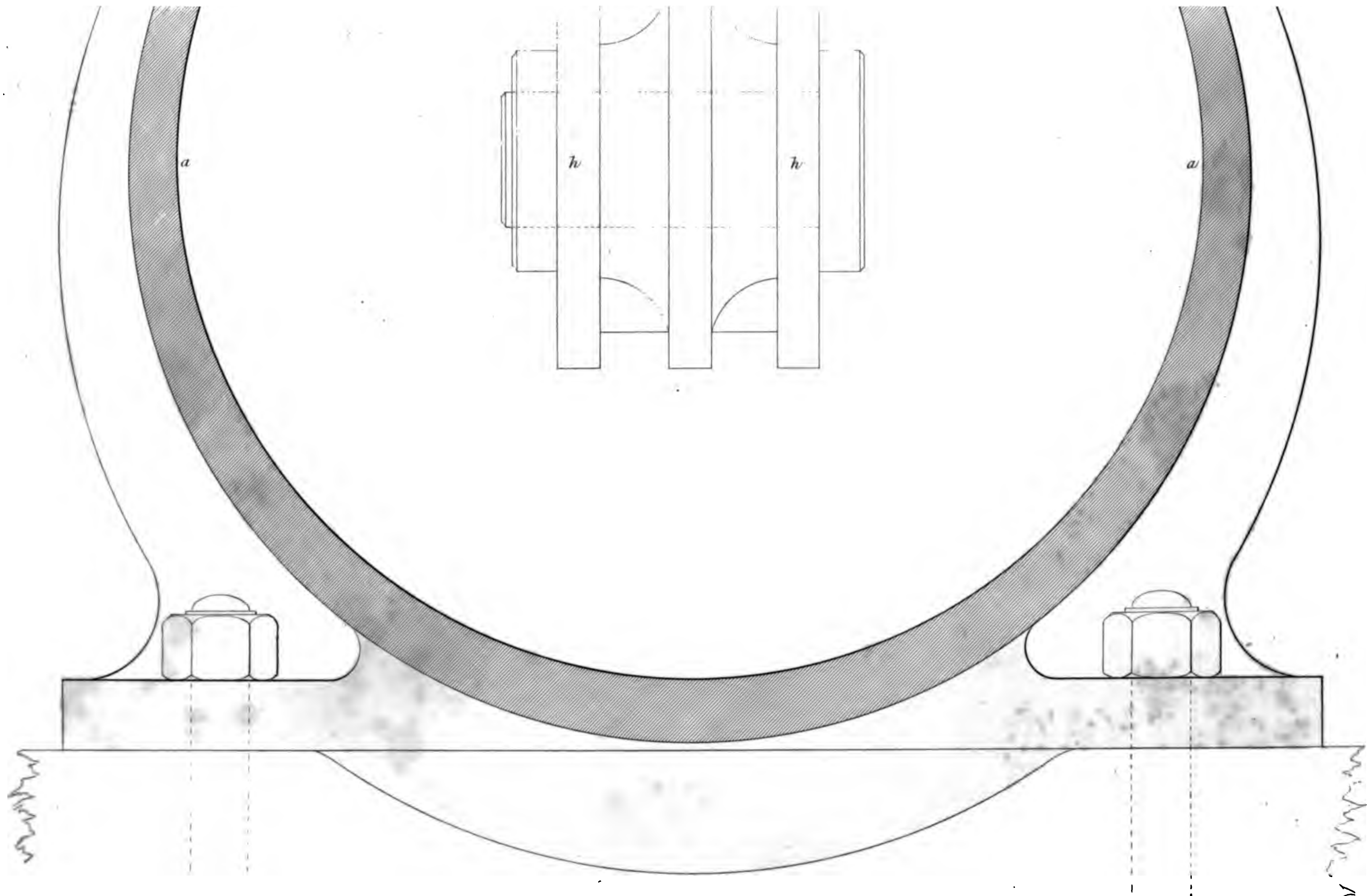



Fig. 1.




R. Mallet, C.E. del.

J.W. Lowry fc.

London, Published by John Weale, 59, High Holborn, 1845.

Plate

# PLAN FOR RELEASING THE PISTON HEAD.

Fig. 3.

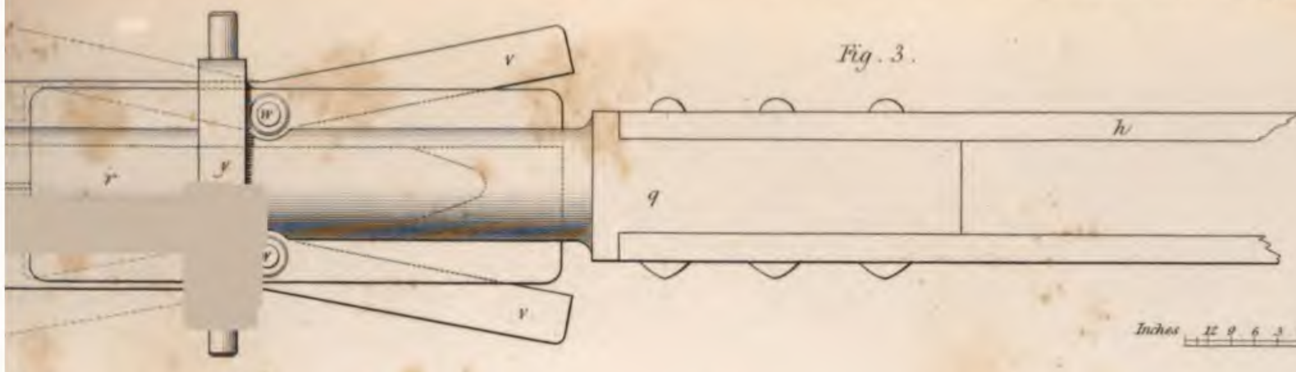
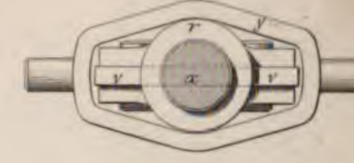



Fig. 4.




Inches 12 9 6 3 0 1 2 3 4 5 6 feet

Fig. 1.

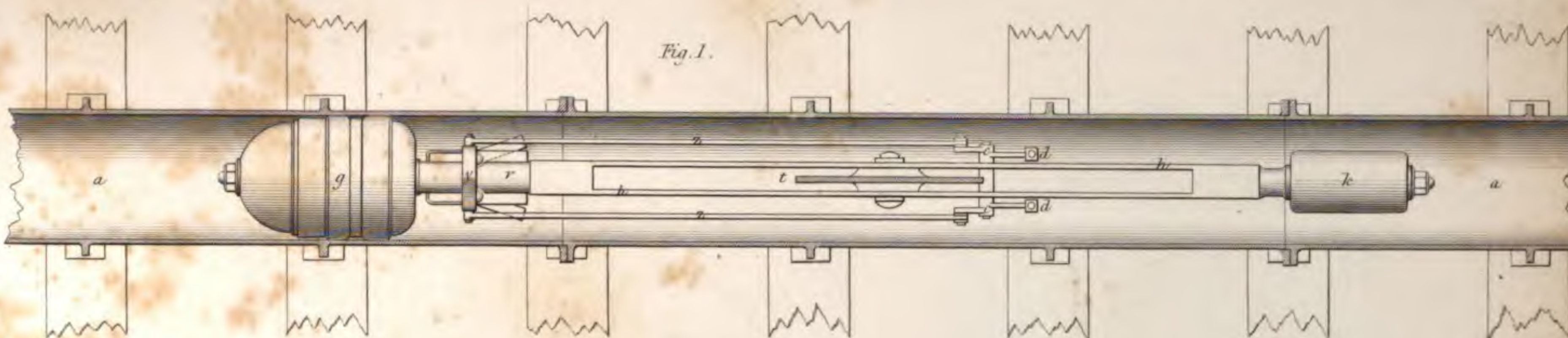
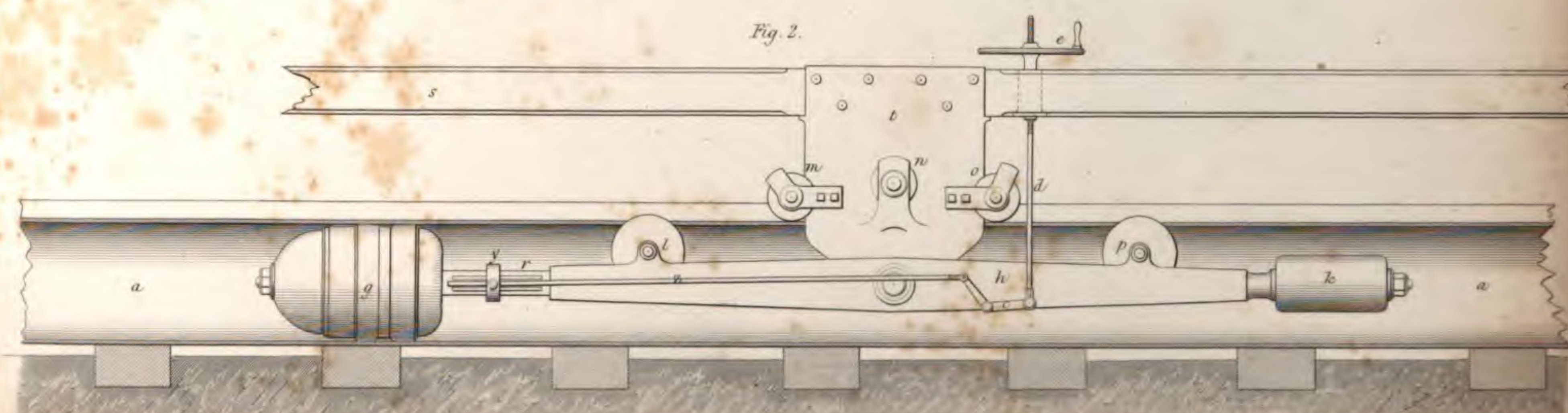



Fig. 2.

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